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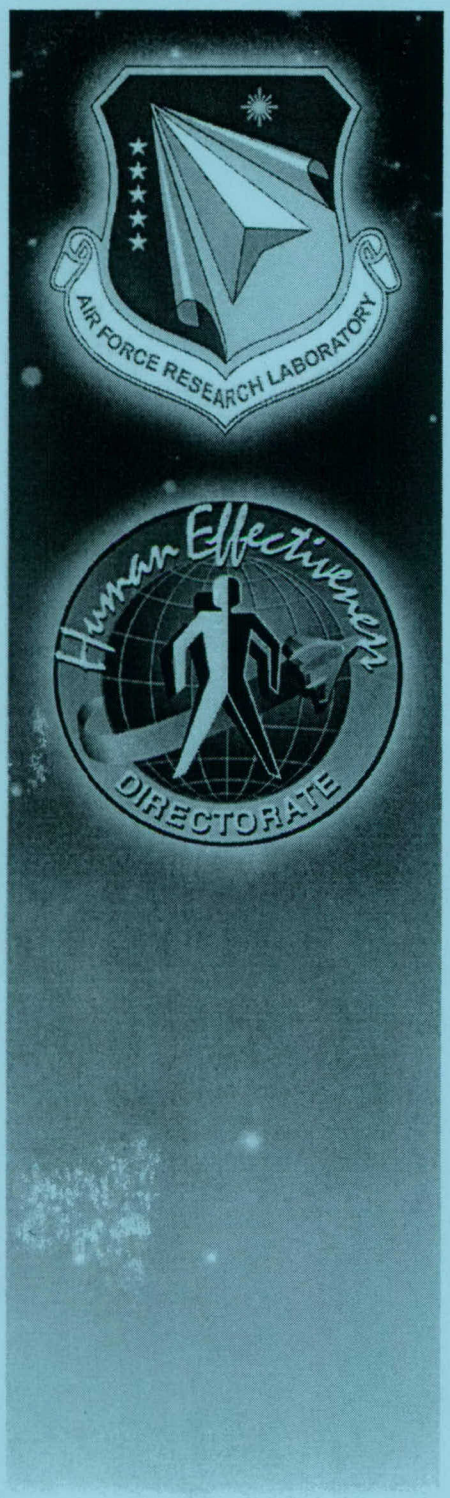

Analytical Tools for Behavioral Influences Operations

Michael Zywien
Ratna Bearavolu
Elisabeth Fitzhugh

SRA International, Inc.
4300 Fair Lakes Court
Fairfax, VA 22033

December 2003

Final Report for the Period August 2003 to December 2003

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Human Effectiveness Directorate
Warfighter Interface Division
Cognitive Systems Branch
2698 G Street
Wright-Patterson AFB OH 45433-7604

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FOR THE COMMANDER

//Signed//

MARIS M. VIKMANIS
Chief, Warfighter Interface Division
Air Force Research Laboratory

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The goal of this project was to identify and evaluate predictive modeling capabilities to support behavior influence operations. The key deliverable was a set of recommendations for mature analytical tools that met the needs of National Air and Space Intelligence Center (NASIC) Behavioral Influences Analysis Division leaders and analysts. The primary focus of this effort was to identify the best Bayesian modeling capabilities for this mission area.

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PREFACE

The SRA International, Inc. team would like to acknowledge our customer, Greg Jannarone, for the opportunity to participate in this effort. We hope that our interim products, this final report, and the attachments provide the value envisioned when he chartered our team.

We'd also like to recognize the support we received from NASIC analysts Jim Morris, Dan Dean, Duane Harrison, and Ken Hammerle. Their insight into how they expect to use modeling tools contributed greatly to our understanding of the criteria we needed to focus on during our data collection and analysis phases.

Gilbert Kuperman, Principal Mathematician in AFRL/HECA, and Capt Tim Gameros, AFRL/HECA PSYOP Researcher, also provided valuable guidance and insight for this project.

We could not have completed this project without the timely and extensive cooperation of many candidate product vendors. We'd especially like to thank Chinatsu Aone (SRA), Dr. Julie Rosen (SAIC), Dr. Jonathan Pfautz and Karen Harper (Charles River Analytics), Max Henrion and Maylene McMillan (*Analytica*), Lionel Jouffe (*BayesiaLab*), Wim Wiegernick (*BayesBuilder*), Edward Olmstead (*Dxpress*), Edward Herskovits (*Ergo*), Anne-mette Christensen (*Hugin*), and Brent Boerlage (*Netica*).

Finally, we'd like to acknowledge our partner, Eric Braeden (NASIC/BPB), who participated as an active member of our project team. Eric provided regular insight and feedback that kept us focused and helped us prioritize our efforts within the project constraints.

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1 EXECUTIVE SUMMARY

The goal of this project is to conduct research leading to identification and analysis of predictive modeling capabilities to support behavior influence operations. The key deliverable is a set of recommendations for mature analytical tools that meet the needs of National Air and Space Intelligence Center (NASIC) Behavioral Influences Analysis Division leaders and analysts. Though text mining and social network analysis tools are important for this customer, the primary focus of this effort was to identify the best Bayesian modeling capabilities for this mission area.

Project work was executed by a government/contractor team of software, intelligence, modeling, cognitive science, operations research, engineering, and psychology experts from NASIC, AFRL, and SRA International, Inc. Project work started in August 2003 and completed in December 2003.

SRA personnel executed this project by dividing the work into four tasks:

- Task 1: Develop capability-based criteria
- Task 2: Market research – identify simulations, models, tools
- Task 3: Rigorous, objective assessment of simulations, models, tools
- Task 4: Develop recommendations regarding acquisition of tools

Detailed Criteria, developed from a thorough understanding of the mission requirements, fell into four criteria categories: *General Features, Input Manipulation, Performance Extensibility*, and *Interoperability.* Using contacts identified by the customer, our own knowledge of the market, and additional investigations using keyword searches of relevant databases and the world-wide-web, the team developed an extensive list of over 80 candidate tools. From this list, we selected a prioritized set for further data collection and detailed analysis.

The Analytical Hierarchy Process (AHP) technique was applied to evaluate and rank the tools. From a performance standpoint, *Hugin* ranks as the optimal Bayesian tool among the alternatives. The next best performance alternatives are *BayesiaLab* and *Netica*. From an "ease of use" perspective, *Netica* and *Analytica* rank highest. Cost and pricing structures are roughly comparable, with the notable exception of *SIAM*, which is available free of licensing fees to government organizations.

Our conclusion, based on this analysis, is that several mature alternatives are available to NASIC. Investment decisions could be made on the basis of this report, but a more sound approach would be to develop and run a benchmark problem scenario on a demonstration version of the highly rated alternatives.

2 BACKGROUND

2.1 Project Description

The goal of this project is to conduct research leading to the identification and analysis of predictive modeling and analysis tools and capabilities to support behavior influence operations. The key deliverable is a set of recommendations for mature analytical tools that meet the needs of National Air and Space Intelligence Center (NASIC) Behavior Influence Analysis Division leaders and analysts.

Project work was executed by a multi-disciplinary, government/contractor team of software, intelligence, modeling, cognitive science, operations research, engineering, and psychology experts from NASIC, AFRL, and SRA International, Inc. Project work started in August 2003 and completed in December 2003.

The customer for this work is Greg Jannarone, Chief of the relatively new Behavioral Influences Analysis Division at NASIC (NASIC/BPB). Gilbert G. Kuperman, Principal Mathematician in the AF Research Laboratory's Human Effectiveness Directorate, and members of his staff also participated in this effort.

Government personnel provided some valuable early guidance and organizational contacts to get us started in this effort. They provided a basic cultural/institutional/psychological framework for the end-state model, desired capabilities that helped us articulate requirements, thoughts on initial evaluation criteria (e.g., easy to use, cheap, can access all information/data sources needed, accurate, reliable, technically mature, risks are manageable, supports/enhances key capabilities, extensible, flexible, interoperable or easy to confederate, supportable, etc.), and finally some valuable leads on people and organizations who could help us get started.

This project is envisioned as a foundation for future work by NASIC analysts. They will use the tools identified in this study to assemble data and build models of individuals and small groups of interest, ultimately leading to the identification and exploration of predictive modeling, simulation, and analysis capabilities in support of USAF (and potentially Joint) behavioral influence operations.

SRA personnel executed this project by dividing the work into tasks (listed below and described in more detail elsewhere in this report):

- Task 1: Develop capability-based criteria to assess predictive constructive simulation, descriptive models, other analytical tools (review NASIC goals for products, end states, analytical processes)
- Task 2: Market research – identify simulations, models, tools
- Task 3: Rigorous, objective assessment of simulations, models, tools

- Task 4: Develop recommendations regarding acquisition of tools

2.2 Architecture Context for This Work

AFDD 2-5 [10], the USAF's Doctrine Document on Information Operations states that *"Influence Operations are an integral part of modern aerospace strategy,"* and defines Influence Operations as one of three core Information Operations capabilities (the others are Electronic Warfare Operations and Network Warfare Operations). According to AFDD 2-5 (2003 draft):

> *Influence operations are focused on affecting the perceptions and behaviors of people, leaders, groups or entire populations. The means of influencing can be physical or informational. The cognitive domain is composed of separate minds and personalities and influenced by societal norms. The cognitive domain isn't homogenous, continuous or even necessarily rational.*
>
> 2003 Draft AFDD 2-5, Chapter 1, Page 3

According to the CONOP for AF Effects Based Operations [11]: "The most significant challenge is to link (trace, understand, predict, assess) actions [alternatives executed by blue forces] to [adversary] behavioral outcomes."

The 29 July 2003 draft AF Psychological Effects-Based Operations (AF PEBO) Architecture OV-2 (Paragraph 2.4.5.2) [12] defines one important node in the architecture as a NASIC Behavior Influences Analysis Branch chartered to *"provide relevant intelligence analysis and products supporting AF PEBO and joint PSYOP targeting and planning."* The stated mission of this organization is to *"conduct human target vulnerability analysis."* An SRA analysis of the trace of this NASIC mission to other elements of the overall Influence Operations and PEBO Architecture is provided as Attachment 1.

Modern intelligence/operations architectures will ultimately deliver increased capability to the warfighter, but only if the architecture enables true integrating strategies among relevant functional experts. Pre-operation estimates of adversary reactions to influences are certainly possible. Individual and small group behavior is rooted in culture, organizational/institutional ties, and unique, "knowable" psychological factors. A holistic, fused, all-source approach is common to all successful operations, and is critical to connect cultural, institutional, and psychological influence factors. However, the potential universe of information and possible relationships to characterize human targets of interest is very large. Therefore, analysts and decision makers need tools to assist them with this mission.

Ultimate customers for the capabilities developed from follow-on efforts to this project will include PSYOP, Deception, HUMINT, Information Operations, Kinetic Operations, and PEBO planners/targeteers.

2.3 Project Definition and Scope

2.3.1 Objectives

Current Project Product Objectives:

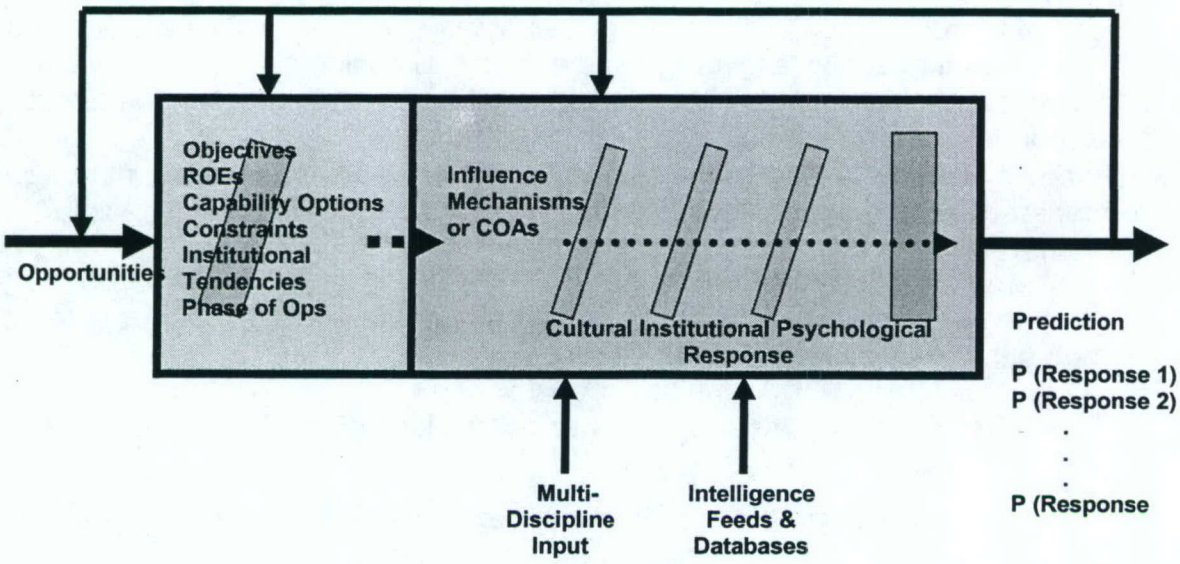
- Recommendations regarding acquisition of COTS/GOTS tool suite, based on rigorous, objective assessment of existing tools
- Include performance, cost, and usability criteria

Customer Process Objectives Supported By This Project:

- Support accurate probabilistic prediction of behaviors in response to input COAs
- Enhance NASIC effort to support effects-based operations
- Determine key psycho/social factors that influence targeted individuals, groups
- Develop templates for relative influence weights/probabilities of influence
- Develop estimative confidence levels for decision-making factors
- Estimation process for "predicting" potential anomalous/irrational behavior
- Probabilistic model of likely decision-making behavior

2.3.2 Project Framework

SRA planners felt it was necessary to fully understand and appreciate the elements of the capability envisioned to meet the needs of our customer. One way to capture this understanding is by building some alternative frameworks for the capabilities. Figure 1 shows two alternative views of an implementing framework for the NASIC vision.



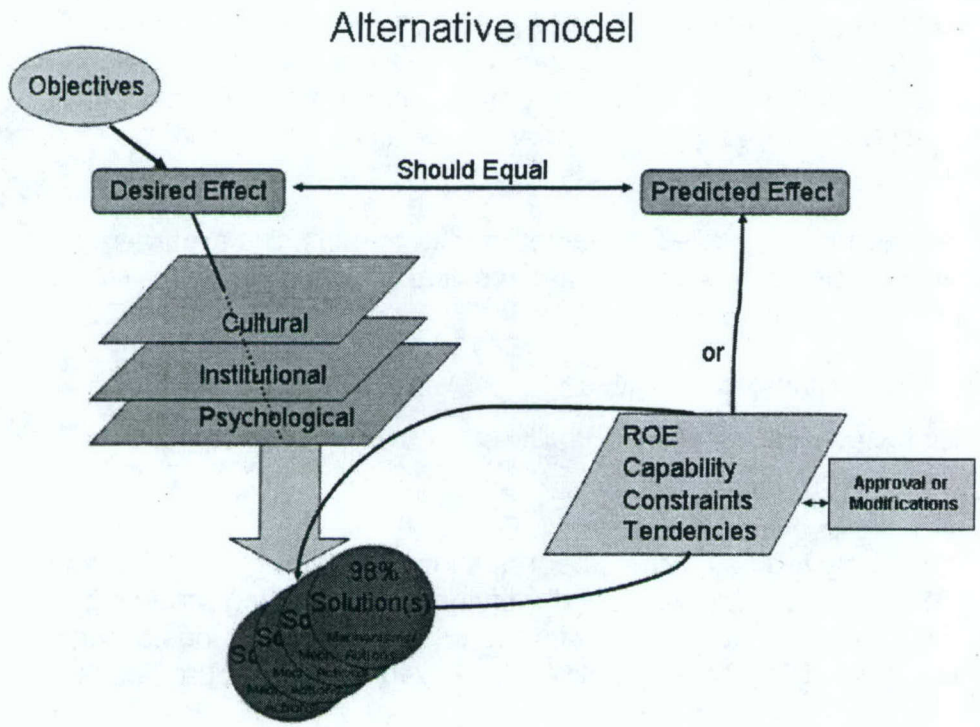


Figure 1. Two alternative Project Capability Frameworks

What are we trying to represent within either of these frameworks? First, there is a need to characterize target (in this case individual human beings or

groups of human beings) vulnerabilities: what target characteristics or attributes can planners and analysts leverage and exploit? In conjunction with this, there is a related but distinct need to characterize target susceptibilities: can the target behave in the way we expect or desire? Is there a predictable path to exploit the vulnerability? Finally, there is the need to determine accessibility: can our target of interest be reached (physically or other) to use the susceptibility and exploit the vulnerability?

Within the layers/filters of the frameworks, note there are categories of target attributes that may be exploitable:

- Psychological attributes – What can we know (emotions, ambitions, motivations, goals, needs)?
- Institutional attributes – What happens when we sever or influence key links?
- Cultural attributes – Which of the numerous candidate cultural attributes do we really care about? Which are the best contributors to a prediction of target behavior?

What we're really looking for in an influence operations framework, then, are influence links that originate in culture, pass through organizations and institutions, into the minds of individuals and groups – thread(s) that reliably link the three planes of influence can put us on the path of a predictive capability. Any selected tool or suite of tools must provide the environment for implementing this capability.

SRA's investigation identified three categories of tools that are needed to implement the analysis framework alternatives illustrated in Figure 1. These categories are:

- Text/Data Mining capabilities
- Social Network Analysis capabilities
- Modeling capabilities

Though this study took all three categories into account, most (90%) of the focus for the SRA team's effort was on identifying and analyzing modeling capabilities. This decision was made, with the full support of the customer, to ensure the main project objectives could be achieved within resource constraints.

3 REQUIREMENTS

3.1 Vision

NASIC Behavioral Influences Analysis Division Vision: Identify influences that can condition, alter perceptions, get the attention of and (ultimately) *effect the behavior* of adversaries (individuals, small decision-making groups).

3.2 Mission

Division Mission: Help the AF build a concept of operations that integrates intelligence and information operations/warfare communities as an *"influence operations capability/system"* (that links actions and behaviors).

3.3 Critical Immediate Need

Critical immediate need: Identify modeling, simulation, and analysis tools and capabilities for *pre-operation estimation* of behavioral influence operation option effects. Need is urgent for tools/capabilities to help analysts establish a *solid analytical foundation* for this emerging mission area.

3.4 NASIC Analyst Input

On 19 Sep 03, an SRA team interviewed four NASIC/BPB Branch Chiefs and the BPB Functional Team Lead [13]. The following paragraphs summarize our interviews. This is presented because it helped form a critical link between high level requirements presented in the PEBO Architecture (see Paragraph 2.2) and the criteria we developed for this study. Analyst questions are provided as Attachment 2.

SRA's main goal was to capture the analysts' focus, expectations, and priorities as it pertains to the current project. Following are some top level observations:

- Analysts with different areas of responsibility will have some overlapping focus areas, needs, expectations, and priorities, but will also have unique needs associated with unique problems in their assigned area.
- Some will focus on small groups and individuals in the near term.
- Some will rely more on organizational and cultural information because detailed information on individuals will be hard to come by.
- Analyst skill set will range from relatively new analysts to 20-year analysis veterans with knowledge and expertise in multiple "INTs."
- Analysts will support a range of customers (intelligence, planners, operators, targeteers, IWF personnel), in deliberate planning and crisis

action modes, primarily at the operations and strategic levels of conflict.

- Typical products will include target profiles, target folder supplements, target system analyses, short-suspense RFIs, pre-positioned O-Plan products, and vulnerability assessments.
- Available information should be the LIMFAC, not the analytic tool set.
- Analysts are very concerned about data overload and data organization, not as much about target models at this point in time. Their priorities focused on user-friendly, data mining (associative pattern mining) and relational database tools first, model building and predictive tools second.
- Analysts do not expect an analytic tool set to replace their knowledge and expertise. They expect that they and their functional experts will provide the knowledge needed for the modeling capability. Aids to help remember and organize knowledge would be welcome capability additions.
- Models will need to handle at least 300 nodes, perhaps up to 3000 nodes.

It became evident after these interviews that the SRA team needed to focus on three technology classes to provide the overall analytic capability needed by BPB analysts: text/data mining tools (to group and summarize documents), link analysis tools (e.g., relational database mining tools to find links between individuals and groups/events/attributes), and modeling tools (to build belief nets). Some of the specific needs/desires for an analytical capability articulated by the analysts include:

- Flexibility to adapt to needs of individual analysts
- Ability to grow in size/sophistication as information set matures
- Ability to search by time relationships, group associations, family relationships, geographic proximity, etc.
- Access classified (multi-INT) and open source information
- Efficient pulling and loading (text, photos, e-files, paper, web pages, etc.)
- Capability to provide reminders or triggers on saved data
- Efficient organization of information so it can be easily found when needed
- Liked the *SIAM* logic train (how it maintains track to source)
- Want tools to help them "lay the evidence out"

- Capability to assign probabilities of given events (not necessarily to have modeling tool assign the probability)
- Spider diagrams will aid social network analysis
- Want interoperability with other agencies' tools (e.g., Visual Links, Analysts Notebook)
- Willing to be trained, but the less training needed, the better
- Data/text mining and relational data capabilities will populate a hierarchy of cultural, organizational, individual events
- Want node/link structure, weights easily tailored to a given target
- Analysts have techniques to search for (and acquire) what they "know they don't know;" analysts would love to have aids to help them with what they "don't know they don't know"
- Volume of information can be overwhelming to an analyst; they need help to sort, organize and prioritize ~ 1300 messages per day (classified/unclassified sources) and improve workload efficiency
- Understanding bias associated with sources is a very important element of the foundation of a predictive capability
- Text is important to everyone, visual information (e.g., pictures) is critical for some due to the shortage of useable text information

It also became evident that there are some things the analysts will not be expecting from an initial analytical tool set:

- Will not be likely to trust search/data mining tools to find all relevant relationships – analyst will still play a major role in reviewing, organizing, and making inferences from the available data
- Multi-media will be useful, but is not a priority now

Consistent priorities for the analysts are, in this order, user friendly sort/organization aids, relational database, links/nodes model structure, Bayesian nets for probabilistic assessments.

These interviews were very valuable to the SRA team. This information reinforced and clarified the user requirements, and facilitated our completion of project Task 1.

3.5 Final Project Requirements Trace

Attachment 1 presents a final requirements trace from Influence Operations doctrine and architecture (requirements) to the criteria we used to evaluate candidate tools and capabilities. This trace ensures that the criteria used to

evaluate promising tools are measuring attributes that contribute to the accomplishment of the vision, mission, and requirements of NASIC/BPB.

4 TASK EXECUTION

4.1 Methodology

The basic methodology used to execute this project is described in the following steps:

- Document/present a project plan
- Ensure requirements are well understood
- Map requirements to criteria (emphasis on modeling tools)
- Establish a list of candidate tools by conducting a market survey
- Develop questionnaire tied to the evaluation criteria
- Phone or personal contact with vendors, followed up with a request to complete the questionnaire
- Enter data from completed questionnaires (follow up as necessary) into a spreadsheet format
- Analyze data
- Report results to customer

The project methodology was executed in phases as described below:

- Phase 1: Detailed planning
- Review available guidance from customer
- Contact people who understand mission requirements
- Develop information collection strategy & methodology
- Assign initial team roles, responsibilities
- Build a detailed project schedule
- Develop an initial capability and criteria list
- Present project plan to customer for feedback
- Phase 2 (Tasks 1 and 2): Refine capabilities/criteria, complete market research
- Identify project/product needs, "alterables", constraints
- Define a product framework
- Identify functions that are needed within the framework

- Identify technology categories needed to implement the functions
    - Develop criteria to evaluate tools, technologies
        - Effects-based criteria (ability to do the job)
        - Other criteria (ease of use, cost, supportability, etc.)
- Phase 3 (Tasks 3 and 4): Collect data, perform assessment on a prioritized subset of the identified tools
    - Identify existing tools that implement required technologies
    - Evaluate tools against approved criteria
- Phase 4: Final report writing, recommendations
    - Recommend right mix of tools
    - Immediate capability expectations

4.2 TASK 1: Develop Criteria

Task: Develop capability-based criteria used to assess "predictive constructive simulation, descriptive models, and other analytical tools" (review NASIC goals for products, end states, analytical processes).

Task 1 Deliverable: Spreadsheet detailing and organizing the project evaluation criteria (Attachment 3).

Using the Requirements Trace described in Section 3 and presented in Attachment 1, the team outlined a basic structure of needs (important characteristics that are "must-haves" for the project), "alterables" (criteria that could be compromised and adjusted to fit the structure of the project), and constraints (attributes that would limit project scope). These needs, alterables, and constraints are presented below:

Needs

- Supports target audience development
- Vulnerabilities, susceptibilities, protections
- Supports identification of a range of influence factors
- Can assign weights to influence factors (culture, institution, psychological)
- Connects influence factors with candidate audience behaviors (links/nodes)
- Relational database handling/management/processing
- Can access all data sources needed (U through TS)

- SIPRNET-compatible
- Reduces analyst workload

"Alterables"

- Easy to use (minimize training requirements)
- Low cost
- Accurate
- Reliable
- Mature
- Risk is manageable
- Extensible (growth capacity)
- Flexible
- Interoperable or easy to confederate
- Supportable
- Source code accessible or stable API

Constraints

- Bandwidth (text, relational database inputs)
- Low level of contractor support needed
- Don't want to use as stand-alone tool (open arch, common formats)

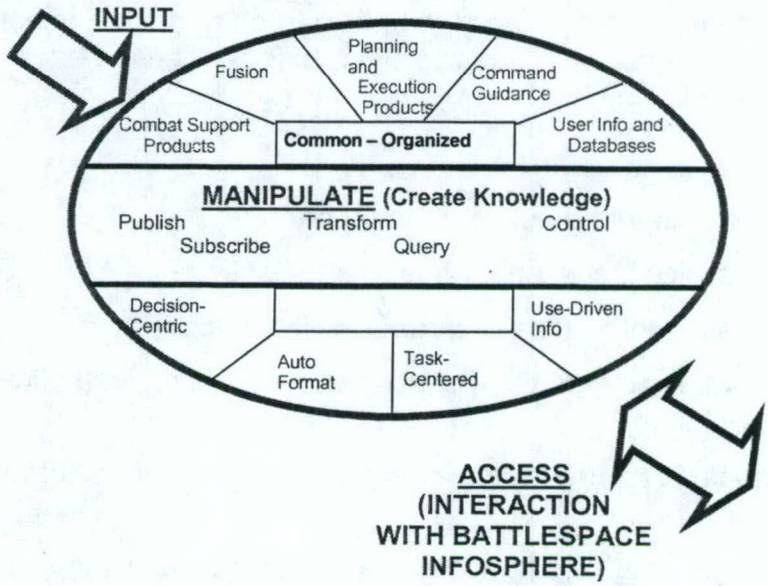


Figure 2. Functions within the Project Capability Framework

Comparing the needs, alterables, and constraints with the model framework described previously, it became clear that certain functions would be required to satisfy the basic design of an Influence Operations analytical capability. These functions are illustrated in Figure 2.

Figure 2 describes three major functions: input, manipulation, and access. Within these functions are sub-functions (e.g., 'publish, subscribe, transform, query,' etc.). Implementing these sub-functions will require specific technologies. Identifying and listing these technologies contributes to another level of understanding with which to build evaluation criteria. An initial cut (developed in the early phases of the criteria development phase) on the specific technologies needed to implement Influence Operations framework functions is presented below:

INPUT Technologies:

- *Identification & authentication*: Source certificates, Secure ID, Source availability, Source discovery, Source ID
- *Access and translation*: Multimedia data capture, Wrapper technology, Heterogeneous data integration, Transformation techniques, Capture plan data, Meeting transcription
- Upstream information: Tagging techniques, Source characterization, Capturing user intent, Pedigree capture (source processing)
- Categorization: Task/data relevance, Ontologies & taxonomies, Expectation driven change detection

MANIPULATION Technologies:

- Storage: Multimedia storage, Resource distribution management, Multilevel secure storage, Seamless access to tertiary storage, High-performance computing, Backup and recovery, High-density mass storage, Data warehousing
- Extraction: Access control, Agent technologies, Intelligent push technologies, Intent inferencing, Dynamic access control, Information usage analysis, User modeling
- Decision Support: Structuring, Advice, Uncertainty portrayal, Tradeoff management
- Aggregation and Fusion: Video compression, Wrapping legacy systems, Information synchronization, Geospatial and temporal indexing, Object extraction for compression, Meta-data language, Data fusion, Information life cycle, Database mediation, Rapid knowledge formation

- Accessing: Collaboration technologies, Self-healing networks, Multi-level access (e.g., security), Parallel access for speed
- Labeling: Uncertainty, Domain-specific taxonomies, ontologies
- Understanding: Dynamic situation modeling, Sensitivity analysis

INFORMATION ACCESS Technologies:

- Routing: Internet, ATM switching, broadcast technologies, etc., Dynamic bandwidth management
- Transmission: Assured delivery, Non-repudiation
- Perception: 3-D Visualization, Natural language, Non-traditional senses, Drilldown, 3-D audio, Tailoring
- Protection: Encryption, Recall of inaccurate information
- User modeling: Info needs models, Dialog management, Context understanding, Intent inferencing
- Communication: Conversational query, Speech, Natural language, Annotation, Domain-specific gesturing
- Collaboration: Sharing, Advanced white-boarding, Domain-specific workflow management, Mixed initiatives, Facilitation

As an example of how a listing of technologies can contribute to an understanding of the criteria needed for this analysis, consider a Decision Support System (DSS). DSS are computer-aided tools that emulate the reasoning process of a human expert making decisions. DSS are currently employed in the fields of business, medicine, law, and environmental sciences. For this project, tools are needed that support decision making. A DSS framework is designed to analyze "what-if" scenarios and help make decisions that involve multi-criteria inputs.

DSS are classified into categories based on the services and features supported. For purposes of this project, SRA considered knowledge-driven DSS and model-driven DSS. Knowledge-driven DSS are pre-programmed with specialized-problem expertise. They contain knowledge about a specific domain, and use this knowledge to aid the decision process of the user. The benefit of this type of DSS is that domain experts can "train" the tool in the initial stages and prepare it so that a user need *not* be a domain expert. The drawbacks are that training of the tool is cumbersome, and it may not be very adaptive to changing scenarios.

Model-driven DSS (*SIAM*™ software is an example) use statistical models to support decision-making. These DSS technologies rely on the data provided by the user (decision tree, weighting of the nodes) for analysis. On the positive side,

no overhead of training the tools is required, and these DSS tend to be adaptive to changing scenarios. The main drawback is that any given user must be a domain expert to apply the tool effectively.

While this is just one example of how a knowledge of the technologies can be applied to develop criteria for tool analysis, one trend should be made clear:

> *All of the technologies evaluated for this project will have advantages and disadvantages, so this meant it was critically important to ensure customer needs were well understood and that the customer was involved in all aspects of evaluation and selection criteria development, prioritization, and weighting.*

As a further illustration of how we used an understanding of relevant technologies to select and prioritize criteria, refer to Table 1. This table presents, for two key categories of tools (Link-Node Analysis and Decision Support Systems), potential techniques used, concepts and theory applied, concerns, and a candidate set of criteria that could be used to evaluate the tool.

Table 1. Illustration of Understanding Technologies

Categories	Link – Node Analysis	Decision Support Systems (DSS)	
Technique Used	Link Analysis - Finds and represents patterns between different variables in the data sets	Model – driven (Decision Analysis Tools)	Knowledge – driven
Concepts/Theory Applied	Data Mining?	Statistical approach (Bayesian Networks)	- Case Based Reasoning (CBR) - Rule Based Reasoning (RBR) - "Learning" concepts
Concerns	How do the tools decide which variables to use to discover patterns? Does the user specify these variables?	- What other information does the system need? - What is the output: Sensitivity Analysis or Impact Analysis	For CBR - Similarity Function - Indexing/Retrieval technique For RBR - Experts define rules - Use data-mining to generate rules
Criteria	- Interactivity with the user - Representation aiding - Ability to interface with multiple databases	- Interactivity with the user - Collaborative support - Qualitative vs. Quantitative weights? - Assessment utilities used	- Interactivity with the user - Predictive capability? - Evaluate data-mining tools?

There are some key terms that will keep coming up in this report and in the attachments. They include:

- Probability Theory
- Decision/Utility Theory
- Bayesian/Belief/Causal/Probability Nets
- Influence Diagrams
- Decision Trees
- Criteria model

Definitions of these terms and a tutorial briefing are provided as Attachment 4. This information can also be found in the Project Glossary (Attachment 11).

After completion of our requirements analysis, breaking down the functions, sub-functions and technologies within the project framework, and in-depth discussions with our customers, the SRA team established the criteria to evaluate candidate modeling tools. Starting at a macro level, we sought capabilities that fit the following criteria:

- Bayesian-based/inferential design, to permit probabilistic, or levels of confidence, outputs
- Analyst-friendly and (relatively) quickly trainable operation
- Links and nodes derivation and representation, especially for "weighting" of the (influence) links and (individual/group) nodes
- Relational data/knowledge base utilization and applications functionality

Detailed Criteria, developed from a thorough understanding of the mission requirements fell into four criteria categories:

- General Features
- Input Manipulation
- Performance Extensibility
- Interoperability

General Features included criteria such as ease of use (which was, in turn, analyzed in further detail with more detailed, tailored criteria), cost, maturity, targeted industries, major clients, type of operating system, recommended hardware, and architecture.

Input Manipulation criteria investigated type of network support, model building capability, type of graph support, conditional probability table specification, model validation, inference algorithm used, analysis techniques, and ability to limit computational complexity.

Performance and Extensibility criteria included the language used for development, availability of source code and API, whether a benchmark was used to evaluate tool performance, maximum number of nodes supported, and error recovery support.

Finally, the *Interoperability* category looked at criteria such as ability to interface with databases, formats used to save models, ability to export models and analysis results to other applications, use of open architecture standards, and capability for group collaboration.

The complete set of evaluation criteria and results from surveys of selected vendor capabilities are captured in Criteria/Data Capture Sheets, a set of worksheets presented in Attachment 3.

4.3 TASK 2: Market Survey

Task: Compile a comprehensive list (within resource constraints) of capabilities that could satisfy some or all of the modeling requirements of this project.

Task 2 Deliverables: Excel spreadsheet listing all candidate tools with notes on selection and elimination criteria; list of contacts and sources of information (Attachment 3); briefing on how we prioritized candidates for detailed data collection and assessment (Attachment 5).

Using contacts identified by the customer, our knowledge of the market, and some additional investigations using keyword searches of relevant databases and the world-wide-web, the SRA team developed an extensive list of candidate tools. This list included over 80 candidates – about fifty of these were judged to be too much in the research phase (too immature) to be reliably evaluated. The remaining (30+) tools were evaluated through another screen – whether they were directly applicable to the customer's problem domain.

The SRA team decided to group the tools based on the underlying technique used for decision modeling. The tools were categorized into four major categories: Bayesian Networks, Influence Networks, Decision Trees and Criteria Modeling (i.e., building hierarchies of criteria and ranking them using AHP or SMART techniques).

The following criteria helped prioritize the class of tools we would carry into the next task/phase (Task 4):

IMPORTANT: Tools that support Bayesian and Influence nets, permit manual construction of nets, and support evidence entry and belief updates (diagnostic inference).

NOT IMPORTANT: Tools that are add-ins to other applications (ex: spread sheet add in), tools that rely on either decision tree technique or Multi-attribute Utility Theory (MAUT) (the problem domain is too big to be represented as one of the above), or tools that provide data mining capabilities given large amounts of data (NASIC analysts may not have large amounts of data in the early stages of implementation).

Tools that used Decision Trees were not considered because we wanted tools that represented decision models compactly. Decision Trees require explicit representation of every possible alternative and this would soon result in a model that is not manageable in size. Criteria Modeling tools were not considered, as they do not allow users to represent uncertainties of how one variable influences another variable. Also, the requirement of a strict ordering among the criteria made Criteria Modeling not applicable to the problem domain.

We considered tools that used Bayesian Networks or Influence Networks for decision modeling as they allow for a compact representation of the model and probabilistic representation of uncertainties of the amount of influence one variable has on the other. For a detailed description of Bayesian Networks and Influence Networks, refer to Reference [4] (at the end of Section 4).

Figure 3 outlines the decision process explained above and lists the tools considered:

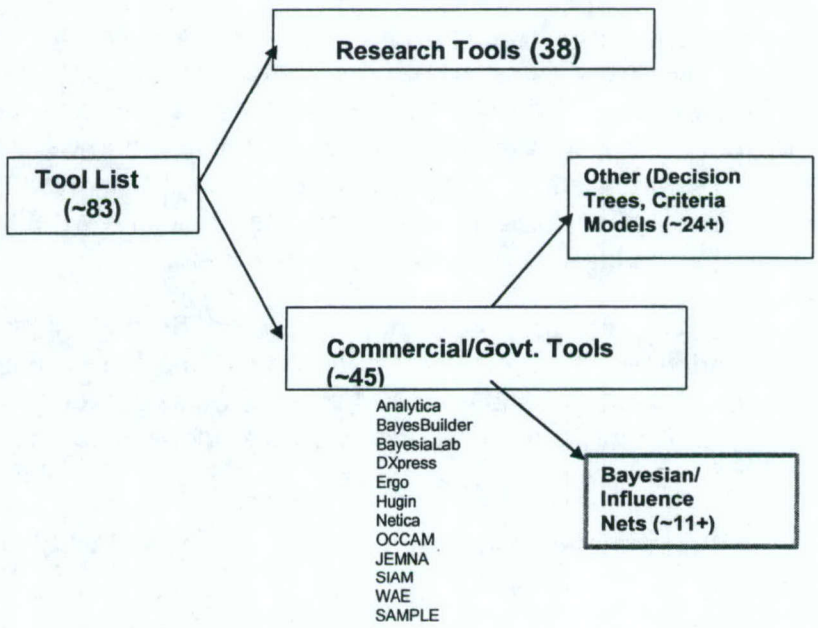


Figure 3. Market Survey Screening Process

4.4 TASK 3: Data Collection

Task: Based on criteria from Task 1, the SRA team developed a questionnaire (Attachment 6) that asked vendors of the "chosen" tools (from Task 2) to characterize their product in terms of our evaluation criteria. Questionnaire responses (Attachment 7) were mapped to the Criteria/Data Capture Sheet (Attachment 3). This information was then used as input to the information analysis task/phase of the project.

Task 3 Deliverables: Raw data collected from candidate tool vendors (Attachment 7); Excel spreadsheet summarizing results from surveys (Attachment 3).

4.5 TASK 4: Data Analysis

Task: Rigorous, objective assessment of simulations, models, tools (obtain demo SW/models/tools and evaluate against criteria from Task 1). Assess how application of tools will support behavioral influence operations.

Task 4 Deliverables: Output from InfoHarvest *Criterium DecisionPlus* analytical tool in Excel format; report on results of analysis

4.5.1 Multi-Criteria Decision Analysis:

After collecting information on the tools (using the questionnaire), the Analytical Hierarchy Process (AHP) technique was applied to evaluate and rank the Bayesian tools. AHP is a Multi Criteria Decision Analysis (MCDA) technique where a hierarchy of criteria is developed. At the top level of the hierarchy is the final goal (which in this case was the best Bayesian tool satisfying most of our criteria). The next level of hierarchy consists of criteria directly affecting the goal. The subsequent levels of the hierarchy consist of subcriteria affecting the criteria above them. The last level of the hierarchy consists of the alternatives that are being evaluated against the criteria. This hierarchy represents the decision model used to evaluate the alternatives.

Once the model is constructed, the next step is to assign weights to all the elements (criteria and alternatives) in the model. The weight of an element represents the amount of contribution/influence that element has towards the criteria above it when compared to the other elements in its level.

For our analysis, InfoHarvest *Criterium® DecisionPlus® 3.0* (*CDP*) was used to determine the best Bayesian tool among all the alternatives. *CDP* is a decision analysis tool that supports AHP and other MCDA techniques to help aid in decision making. *CDP* provides a GUI to build the hierarchies; the user develops the decision hierarchy and then, using the AHP or SMART analysis technique, ranks the elements in the hierarchy. A scale of five ranking gradations is supported by the tool to assign ranks to the elements. Ranks can be assigned

numerically or verbally. The following table (Table 2) summarizes the ranking scale available for direct AHP ranking in *CDP*.

Table 2. AHP Ranking Scale in *CDP*

Numerical	Verbal
100	Critical
75	Very Important
50	Important
25	Unimportant
0	Trivial

4.5.2 Criteria Selection & Ranking:

The criteria selected were based on the questionnaire. Questions that every tool answered similarly (e.g., *Does the tool provide GUI support for model building?*) or those that had responses that were not quantifiable (e.g., *Who are the tool's major clients?*) were not considered as part of our criteria. Subsets of questions from the questionnaire were selected as criteria for every category in the questionnaire.

The decision model for choosing an optimal Bayesian tool was developed as a two stage model. The first stage involved developing decision models for every category in the questionnaire and ranking the alternatives within each category. These decision models were called the sub-goal models. The final model was developed by grouping the four sub-goal models together as criteria for the final goal.

Once the sub-goal and final goal models were built, input from the customer was taken to assign preference ordering of the criteria and subcriteria within all the decision models. These preference orderings were then translated into the ranking scale provided by *CDP 3.0*.

The following tables (Tables 3-7) summarize, for every category, the questions that were considered as criteria/subcriteria and their associated weights. Every table is followed by a *CDP* hierarchy diagram of the table (Figures 4-8), showing the normalized relative weights of criteria and appropriate levels of subcriteria.

Category - General Features

Table 3. General Features Criteria and Relative Weights

Criteria	Rel Wt	Subcriteria	Rel Wt	Questionnaire questions used from General Features category
Maturity	2	>5 years	1	Question 2. Introduced a subcriteria of less than or greater than 5 years
		<5 years	2	
OS_Support	3	MultipleOS - Win, Linux, (and/or) Mac	1	Question 5.
Architecture	1	Client-Server	1	Question 7a

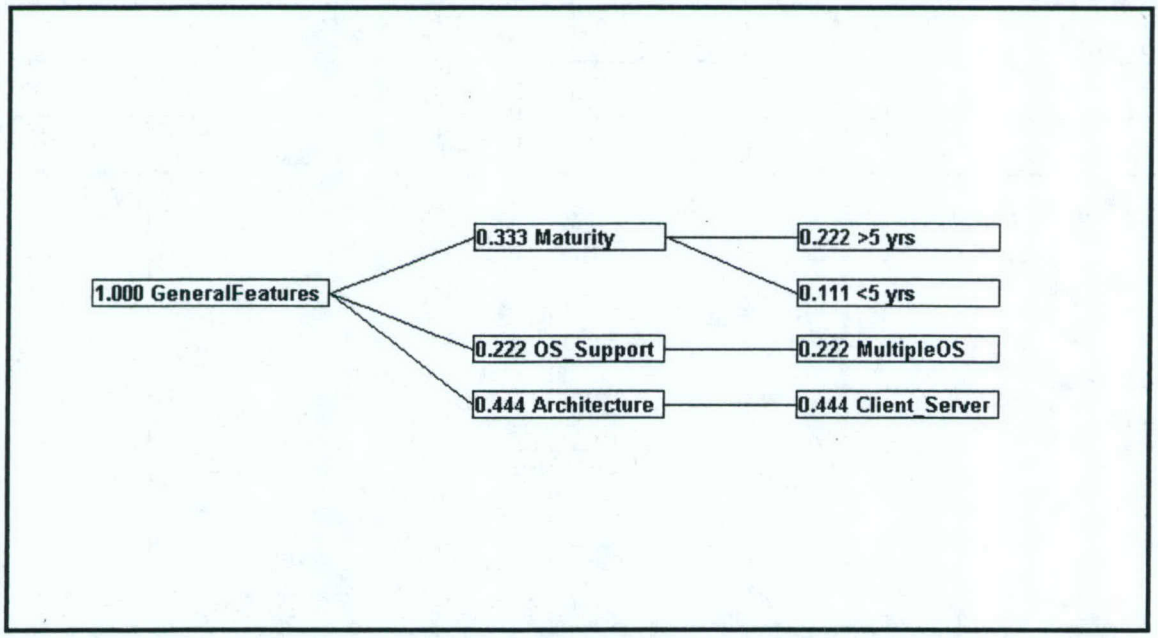


Figure 4. Normalized relative weights for General Features criteria

Category – Input Manipulation

Table 4. Input Manipulation Criteria and Relative Weights

Criteria	Rel Wt	Subcriteria	Rel Wt	Questionnaire questions used from Input Manipulation category
Decision Node Support	3			Question 1b
Analysis Technique	1			Question 7
Mixed Graph Support	3			Question 3c
Probability	1	Equations	2	Question 4 (b,c,d)
		Learning	3	
		Other	3	
		Noisy-Or	1	Information for this was gathered later on
Virtual Evidence Support	2			Information for this was gathered later on
Inference Algorithm	2	Exact	1	Question 6
		Approximate	2	
Structure Learning	3			Question 2b

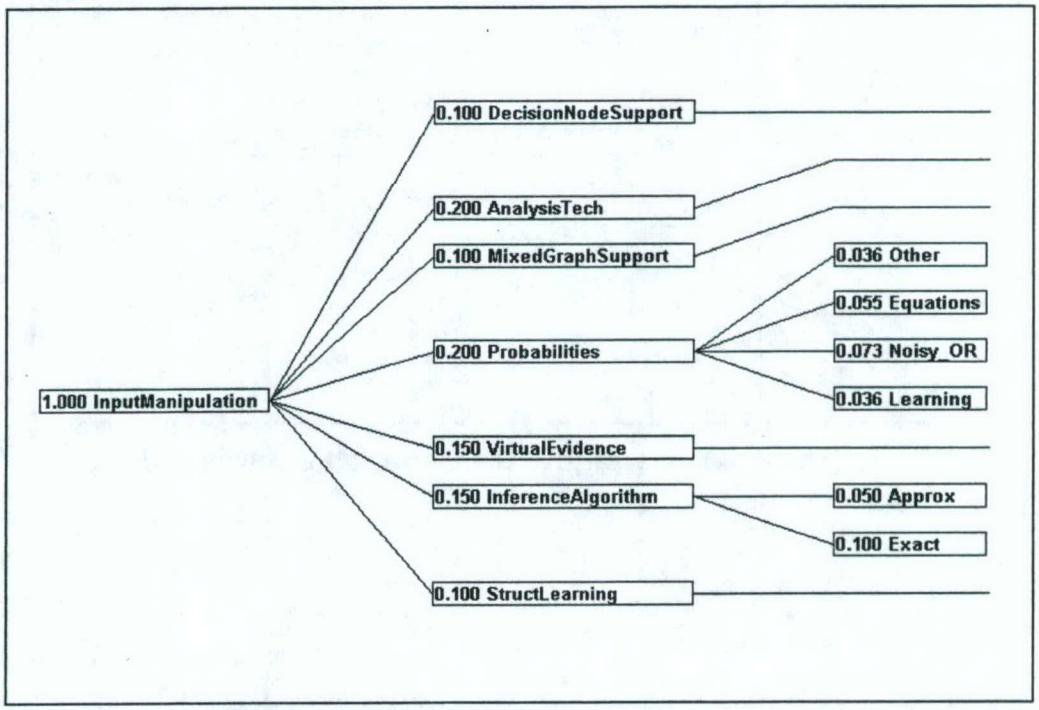


Figure 5. Normalized relative weights for Input Manipulation criteria

Category – Performance and Extensibility

Table 5. Performance and Extensibility Criteria and Relative Weights

Criteria	Rel Wt	Subcriteria	Rel Wt	Questionnaire questions used from Performance & Extensibility category
API Availability	3			Question 3
GUI	2	C/C++	1	Question 1a
		Java	2	
Computational Engine	1	C/C++	1	Question 1b
		Java	2	

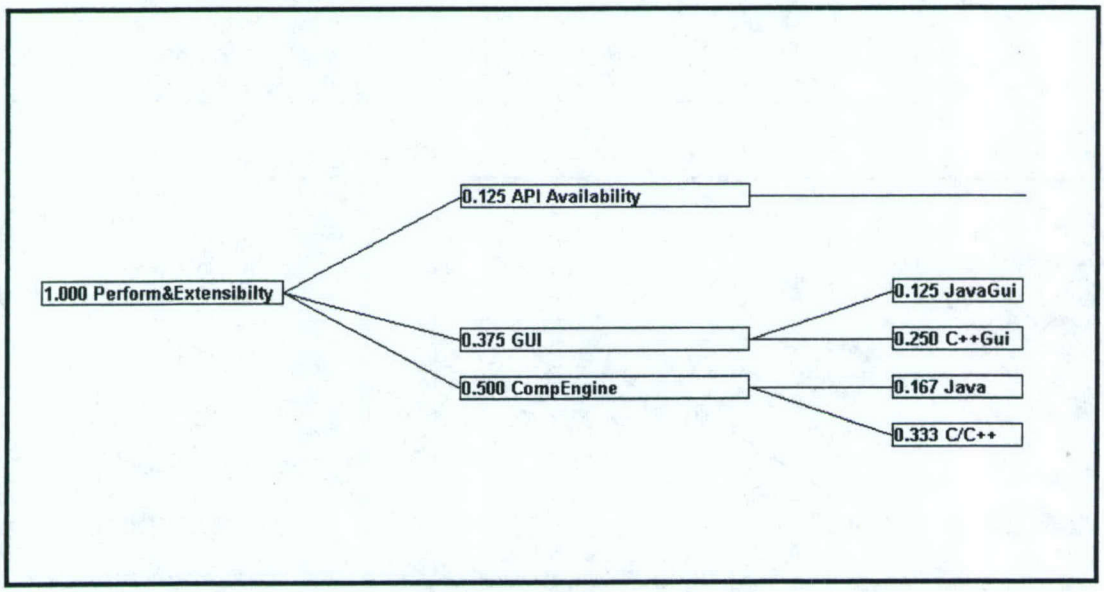


Figure 6. Normalized relative weights for Performance & Extensibility criteria

Category – Interoperability

Table 6. Interoperability Criteria and Relative Weights

Criteria	Rel Wt	Subcriteria	Rel Wt	Questionnaire questions used from Interoperability category
Database Input Access	2	Use ODBC	1	Question 1(a,b,c)
		Direct	3	
		Save Models	2	
		SQL Interface	3	
Export Analysis Report	1			Question 4
OpenModelFormat	2			Question 2
Export/Import Model	3			Question 3. Modified question by grouping the ability to Import nets built by other applications.

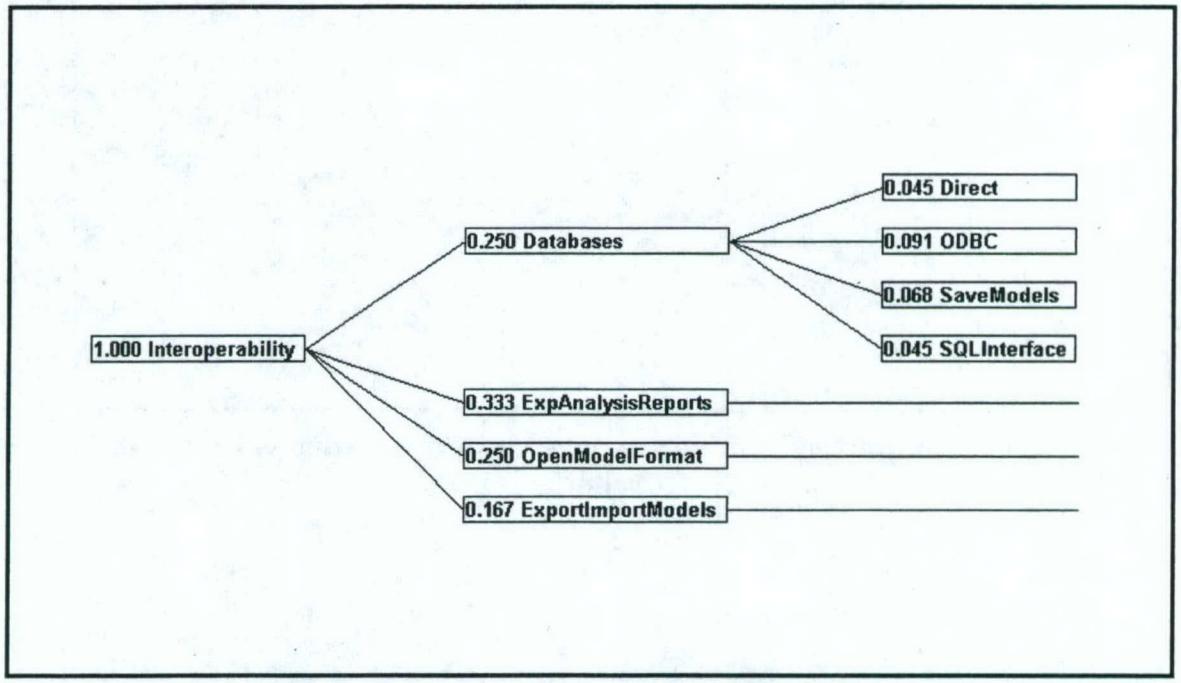


Figure 7. Normalized relative weights for Interoperability criteria

4.5.3 Final goal – Selecting the optimal Bayesian tool

Table 7. Summary Criteria and Relative Weights

Criteria	Rel Wt
General Features	3
Input Manipulation	1
Performance & Extensibility	2
Interoperability	2

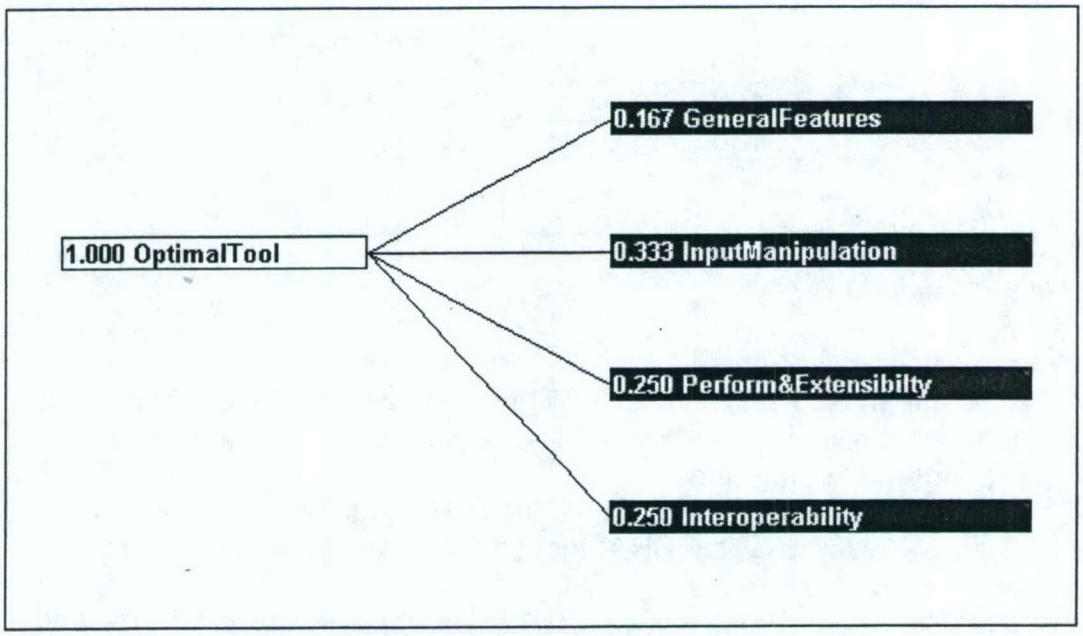


Figure 8. Normalized relative weights for summary criteria

4.5.4 Ranking the Bayesian Tools:

The tools were ranked against all the criteria/subcriteria in the four decision models. Ranks were assigned based on the information gathered about the tool and the extent to which a tool could perform the criteria. For example, with criteria like Maturity of tool greater than five years (in the GeneralFeatures sub-goal model), tools were simply assigned 100% if they were in the market for greater than five years and assigned 0% for the subcriteria *Maturity,* less than five years. But for criteria like ExportAnalysisReports (in the Interoperability sub-goal model), although all the tools provided some capability to export analysis reports, there was a wide range in the extent to which it could be done. For criteria like these, we assigned scores based on the extent of capabilities provided by the tool and not just based on if the tool said yes to the criteria in the

questionnaire. The following tables (Tables 8-11) summarize the ranks assigned to the tools. Each table is followed by additional notes that explain in detail some of the scores assigned.

Category – General Features

Table 8. Tool Rank for General Features Criteria

Tool Name	Maturity		OS Support	Architecture
	> 5 yrs	< 5 yrs	MultipleOS	Client-Server
Analytica	100	0	75	75
BayesBuilder	0	100	0	75
BayesiaLab	0	75	100	0
Dxpress	100	0	0	100
Ergo	100	0	100	0
Hugin	100	0	100	75
Netica	100	0	100	75
SIAM	100	0	75	100
Bnet2000	50	0	100	0

Additional Notes:

- For subcriteria < 5 yrs,
  - *BayesiaLab* is given a score of 75 because we wanted to differentiate between tools that are about 4-5 years old versus tools that have 1-2 years of market maturity.
  - *Bnet2000* is given a score of 50 because this tool was only used within Charles River Analytics (CRA) Inc, and does not have any commercial maturity outside CRA.
- For subcriteria Client-Server support, *Analytica*, *BayesBuilder*, *Hugin* and *Netica* are given a score of 75 because there is no built in feature for Client-Server Architecture. This is accomplished using an Application Program Interfaces (API).
- For subcriteria MultipleOS, we were distinguishing between tools that supported different kinds of OS (Windows, Linux, Mac) versus that supported only one kind of OS. A score of 100 was given if the tool supported Windows, Linux and/or Mac.
  - Although *Analytica* supports more than one OS (Windows and Mac), it was given a score of 75 because it did not support Linux (Customer emphasized that the tool has support for Linux).
  - Although *SIAM* is meant to support Windows and Linux (since it's developed in Java), its not tested on Linux. Due to this, it was given a score of 75.

Category – Input Manipulation

Table 9. Tool Rank for Input Manipulation Criteria

ToolName	DecisionNode Support	Analysis Tech	MixedGraph Support	Probabilities				Virtual Evidence	Inference Algorithm		Structure Learning
				Equations	Noisy-Or	Learning	Other		Exact	Approximate	
Analytica	100	75	0	100	0	0	0	0	0	100	0
BayesBuilder	0	50	0	0	100	0	0	0	100	0	0
BayesiaLab	0	75	100	100	100	100	0	100	100	100	100
Dxpress	0	75	0	0	100	0	25	0	100	0	0
Ergo	0	25	0	0	0	0	0	0	100	0	0
Hugin	100	75	100	100	100	100	0	100	100	0	100
Netica	100	75	0	100	100	100	0	100	100	0	0
SIAM	100	75	0	0	100	0	100	0	50	0	0
Bnet2000	0	50	0	75	75	100	0	100	100	0	0

Additional Notes:

- With Bayesian Nets, following are some of the analysis types supported:
  - Conflict Analysis – Task of determining whether the individual pieces of evidence entered into the net support same conclusion or support contradicting conclusion.
  - Sensitivity Analysis – given a query node, how much can it be impacted by findings at other selected nodes in the net?
  - Value of Information – ability to order the set of evidence nodes in the order of value they will bring to the findings at other nodes.
  - Most Probable Explanation – generation of probabilities that reflect the most probable explanation of the evidence entered.
  - If the tool supported more than two of the above analyses, they were given a score of 75 and tools that supported less than two were given a score of 50.
  - With *Ergo*, a score of 25 was given because Sensitivity Analysis is supported only through API and not through GUI.
- For the Subcriteria Other under Probabilities criteria, *Dxpress* was given a score of 25 to account for the additional features it supports to simplify the probability entry process.
- For the Subcriteria Equations and Noisy-Or under Probabilities criteria, *Bnet2000* was given a score of 75 because these features are supported thru Excel and not directly within the tool.
- For the Subcriteria Exact under Inference Algorithm criteria, *SIAM* was given a score of 50 because it does not support the regular exact algorithm for Bayesian Inferencing. Although, *SIAM* using Causal Strength Logic (CAST) algorithm, minimizes the overhead incurred by the traditional Bayesian Inferencing, it does not provide features that support diagnostic or causal inference upon entering new evidence.

Category – Performance and Extensibility:

Table 10. Tool Rank for Performance and Extensibility Criteria

	Computational Engine		GUI		API Availability
	C/C++	Java	C++	Java	
Analytica	100	0	100	0	100
BayesBuilder	100	0	0	100	100
BayesiaLab	0	100	0	100	100
Dxpress	100	0	100	0	100
Ergo	100	0	100	0	100
Hugin	100	0	0	100	100
Netica	100	0	100	0	100
SIAM	0	100	0	100	0
Bnet2000	0	100	0	100	75

Additional Notes:

- For the tool performance availability criteria, scores were assigned based on the information that was made available to us by the tool vendor.
- For criteria API availability, *Bnet2000* was given a score of 75 because negotiation is involved.

Category – Interoperability

Table 11. Tool Rank for Interoperability Criteria

Tool Name	Databases				Export Analysis Reports	OpenModel Format	Export/ Import Models
	Direct	ODBC	Save Models	SQL Interface			
Analytica	0	100	100	100	100	100	100
BayesBuilder	0	0	0	0	25	0	100
BayesiaLab	0	100	0	100	100	100	100
Dxpress	0	0	100	0	25	0	0
Ergo	0	0	0	0	75	75	0
Hugin	100	100	0	0	50	75	100
Netica	100	100	0	100	75	75	100
SIAM	0	0	0	0	100	100	100
Bnet2000	0	0	0	0	75	100	100

Additional Notes:

- For the criteria ExportAnalysisReports scores were assigned based on the following:
  - If the tool provided a graphical display of what-if and inference results; capability to copy and paste the network to other applications (MS

Word, PowerPoint, etc) by a simple click and drag, it was a given a score of 100.
- If the tool primarily generated textual reports and allowed the user to select and paste the results and the nodes from other networks, to other application (click and drag), it was given a score of 75.
- If the tool allows the user to save the network and the results as a file that could be opened later, it was given a score of 50.
- If the tool allowed the user to only save the case files, it was given a score of 25.

- For the criteria Open Model Format, *Ergo* is given a score of 75 because the open format feature is not as efficient as saving the model in the proprietary format; Although *Hugin* does not support any standard formats (XML, XBN, BIF etc), it is given a score of 75 because the format it supports, .net, is exportable to many other Bayesian Net tools; *Netica* is given a score of 75 because the Open Model Format feature is implemented, but not yet made available to the users.

4.5.5 Discussion of the Results:

Results were generated in two phases. The first phase involved generating scores for the tools within the four sub-goal models – General Features, Input Manipulation, Performance & Extensibility and Interoperability. These results were then combined together into a final decision model, as seen in Figure 8. The four criteria in Figure 8 are essentially soft-links to the four sub-goal models. The results from the sub-goal models are propagated to the final model, where they are combined to generate final decision scores.

For every decision model, *CDP* displays the results in a decision score window. A decision score window displays the decision score of each of the alternatives in the model in a horizontal bar chart. Each line shows the name of the alternative, the value of the decision score, and a horizontal bar reflecting the value of the decision score [1].

For further analysis of the decision scores, *CDP* provides a feature that displays a breakdown view of contributions from each of the criteria toward the decision score of the alternative. Following are decision score windows and contribution by criteria windows (Figures 9-16) for all the sub-goal models and the final model.

Category – General Features (GF)

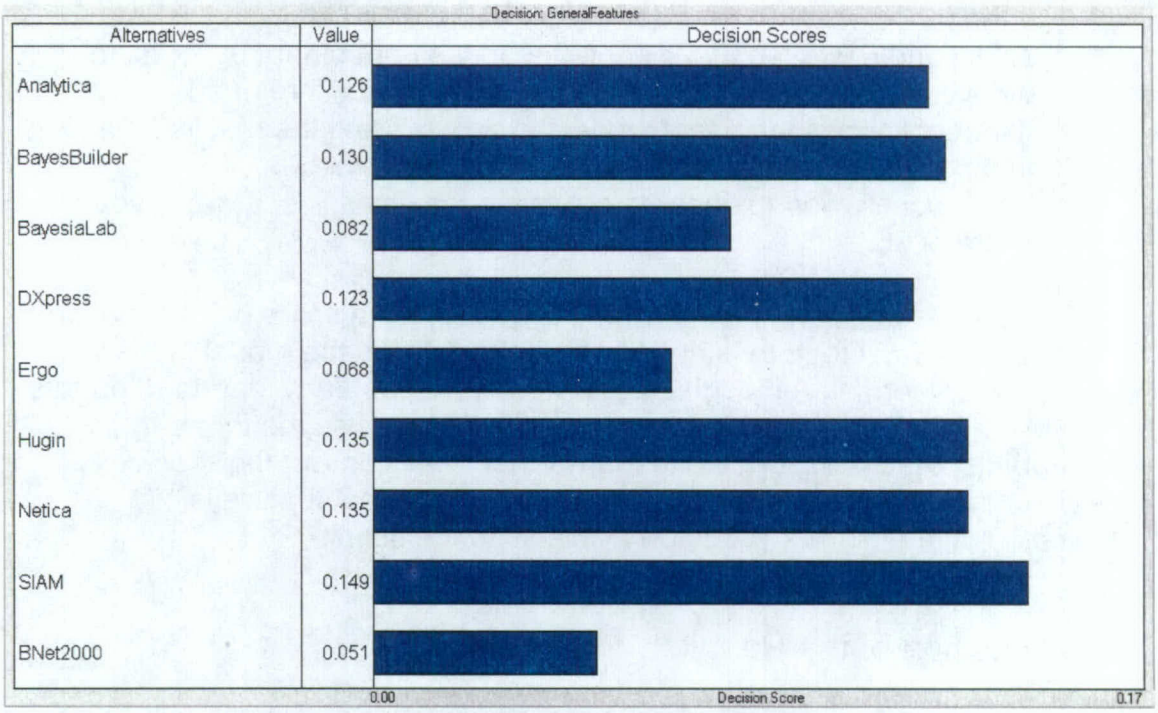


Figure 9. GF Decision Score

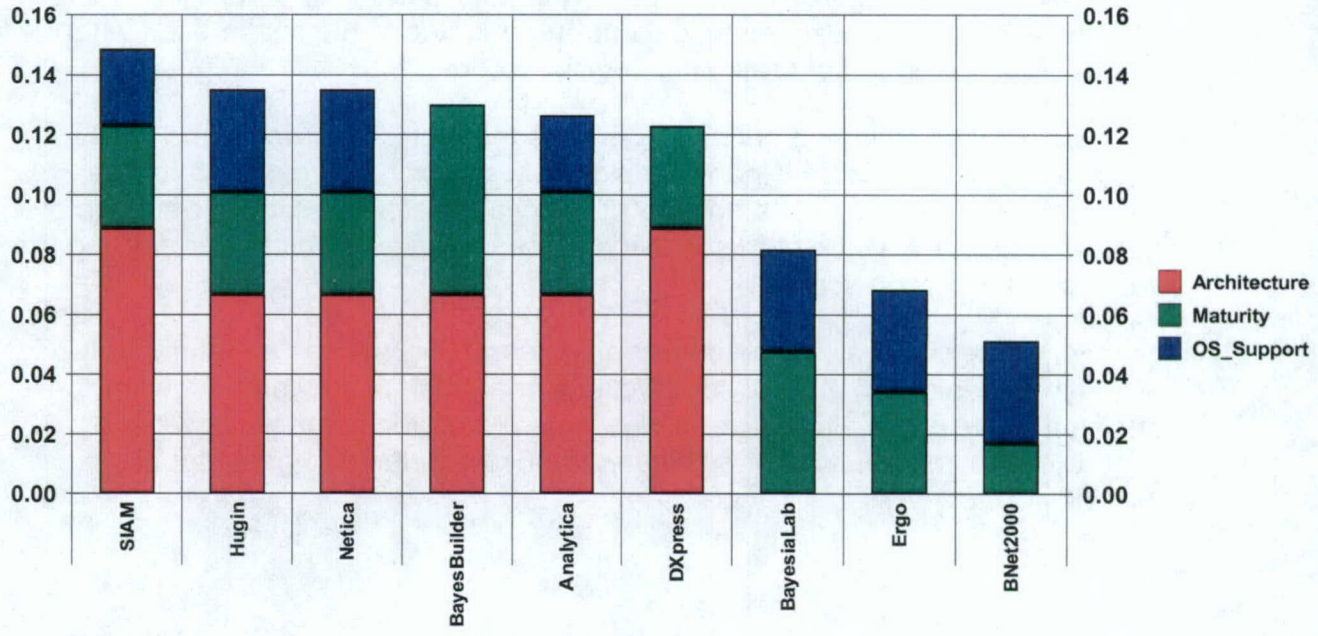


Figure 10. GF Contribution by Criteria

Category – Input Manipulation (IM)

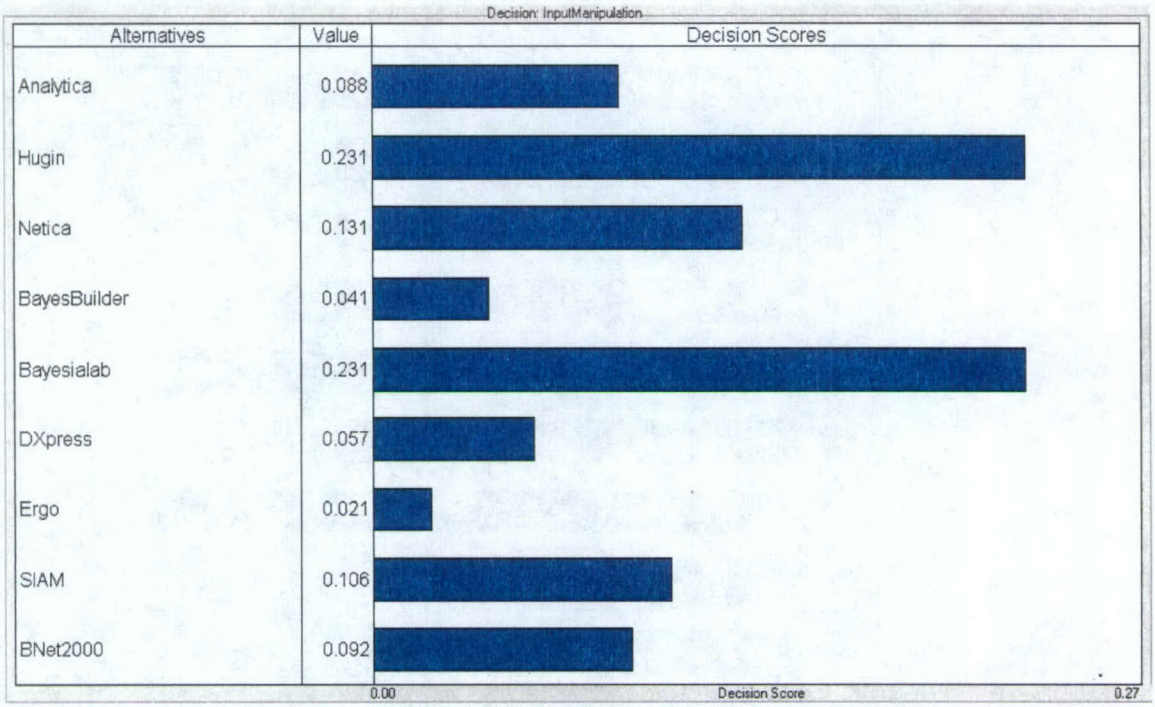


Figure 11. IM Decision Score

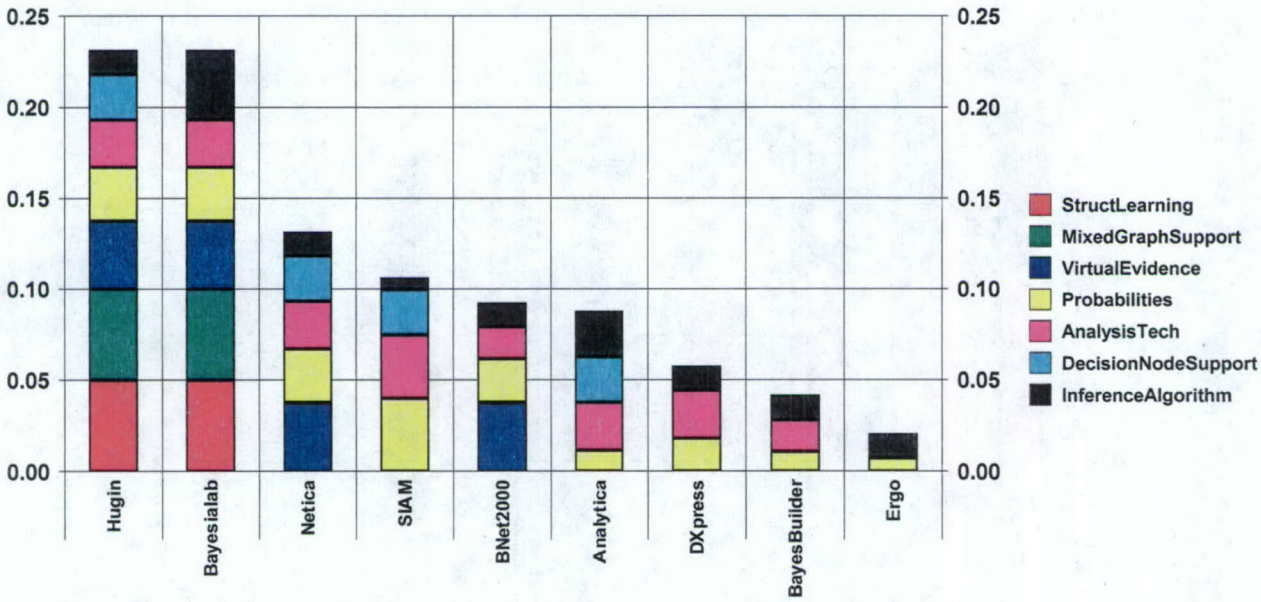


Figure 12. IM Contribution by Criteria

Category – Performance Extensibility (PE)

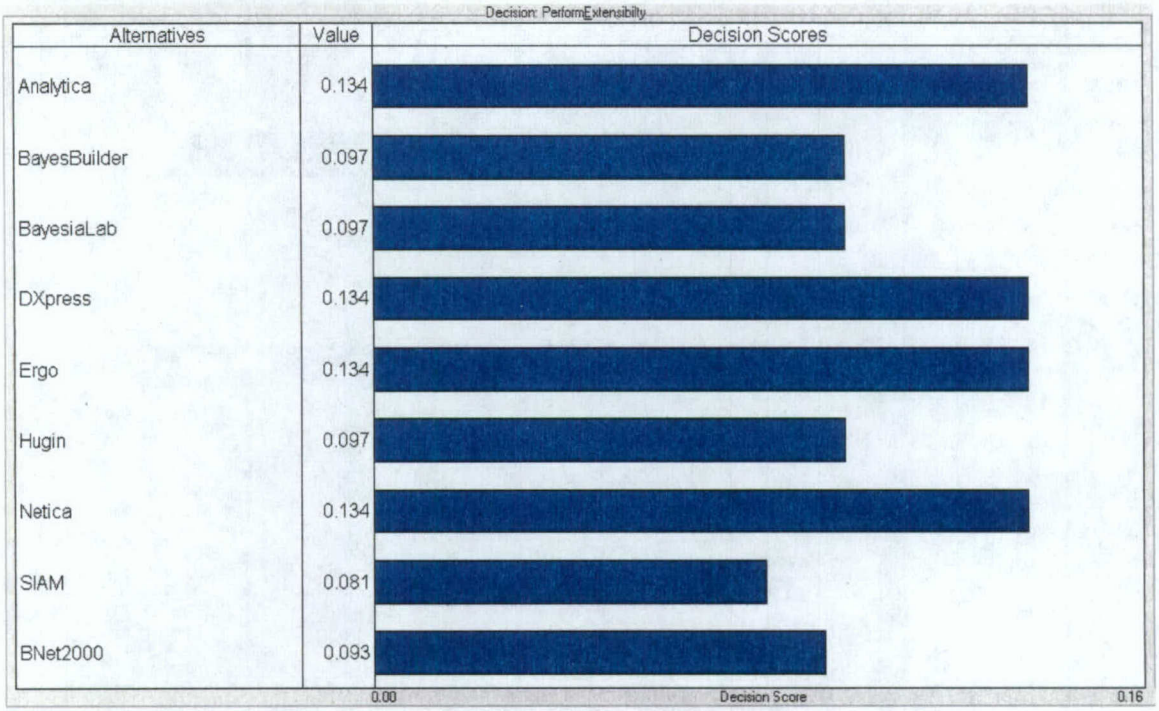


Figure 13. PE Decision Score

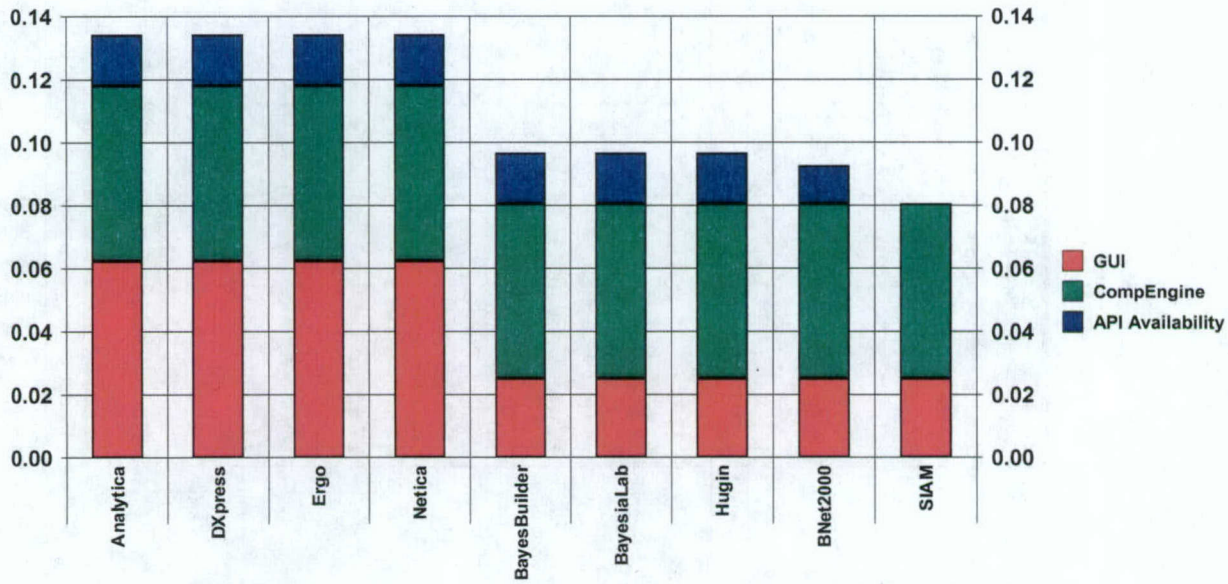


Figure 14. PE Contribution by Criteria

Category – Interoperability (IO)

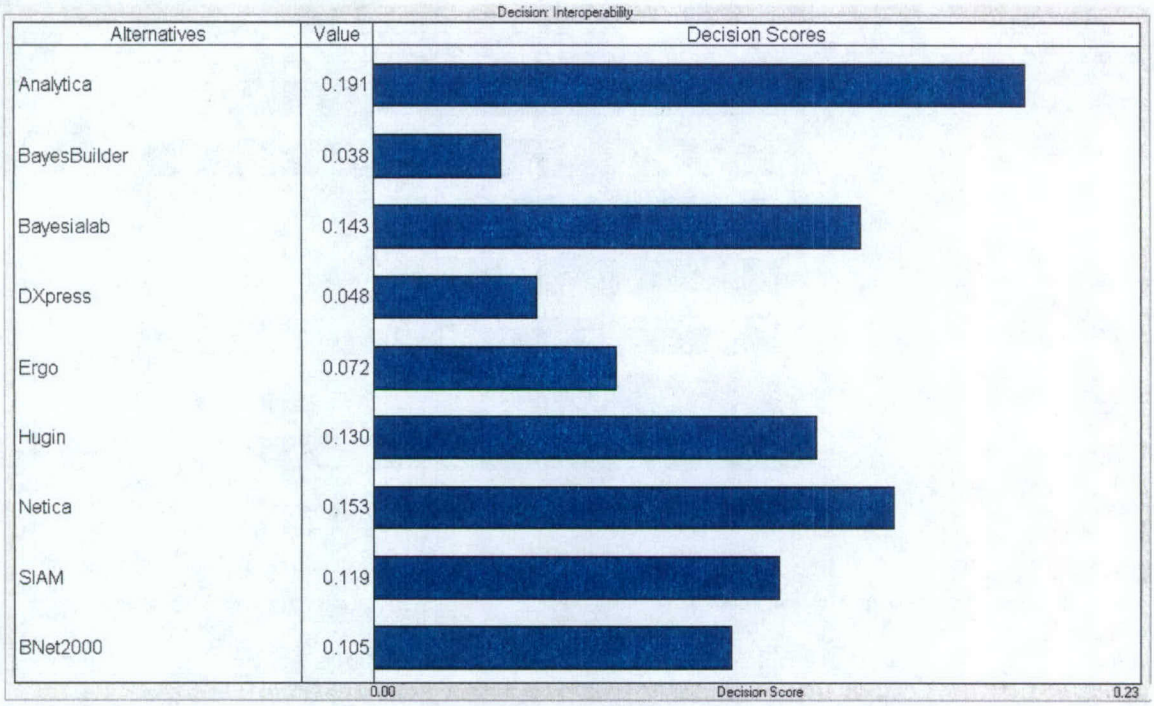


Figure 15. IO Decision Score

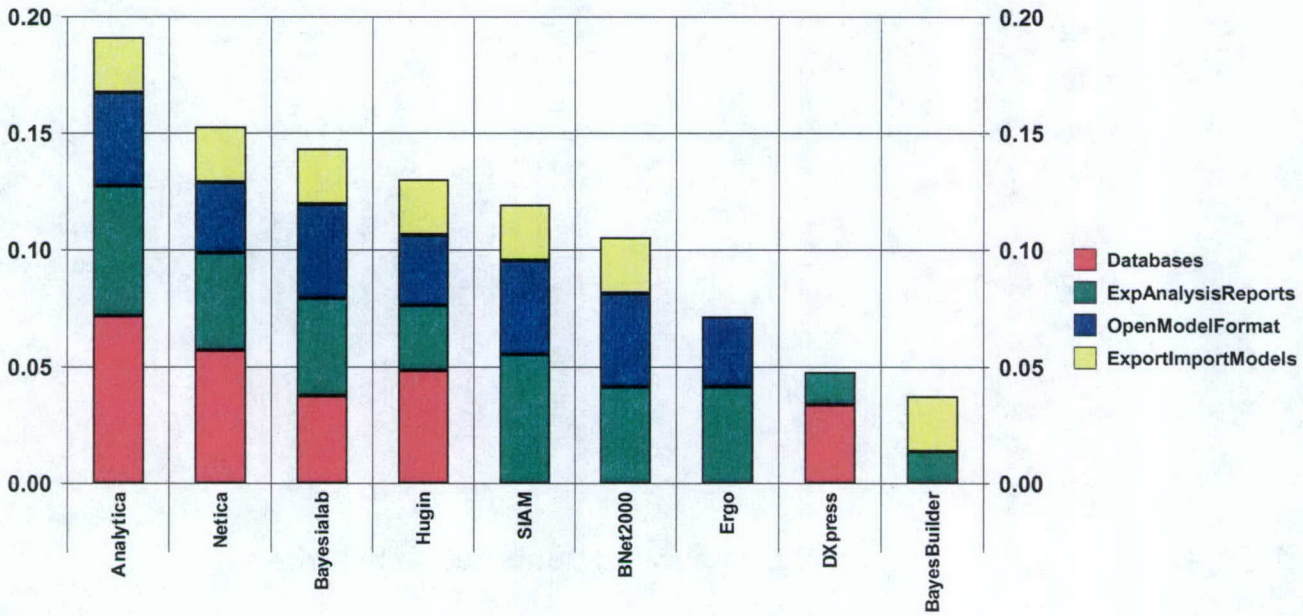


Figure 16. IO Contribution by Criteria

4.5.6 Scores from integrating the four sub-models into a final model

Figure 17. Integrated Decision Score

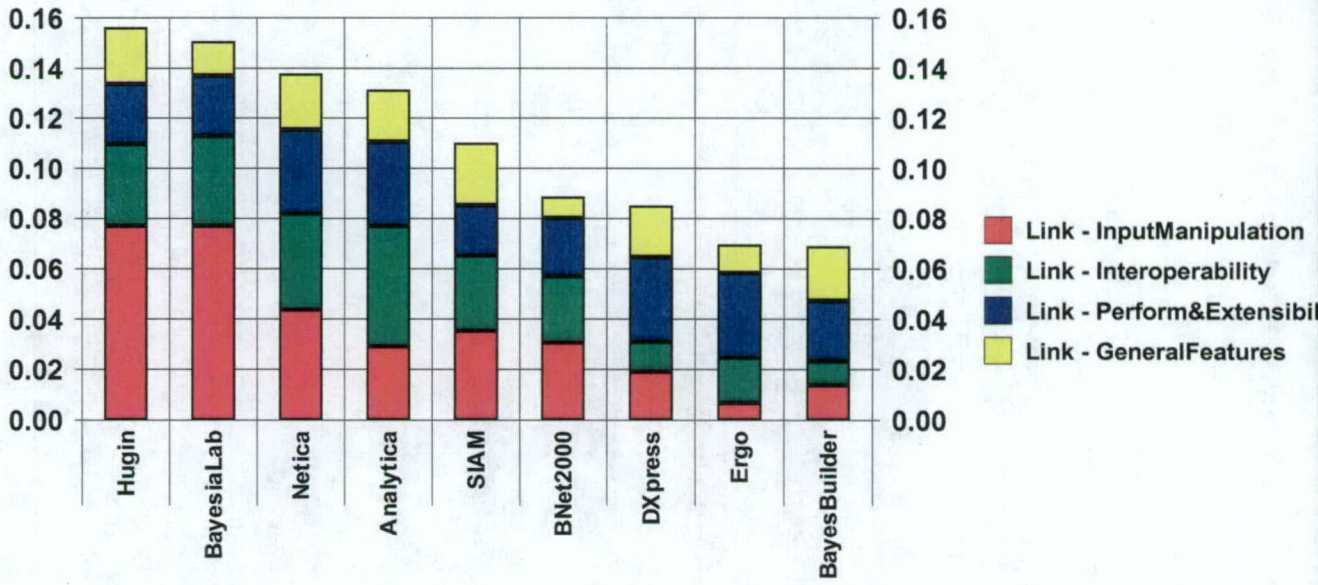


Figure 18. Integrated Contribution by Criteria

From the final goal decision score window (Figure 17), *Hugin* ranks as the optimal Bayesian tool among all the alternatives (though others are close). From the final goal contribution by criteria window (Figure 18), it can be further seen that the score from Input Manipulation criteria had the maximum contribution towards the decision score of *Hugin*. The reason for this is that the criteria Input

Manipulation carried the maximum weight with respect to the final goal of choosing an optimal tool and within the Input Manipulation decision model, it can be seen that *Hugin* ranked the highest. This gave *Hugin* a lead compared to the other tools.

BayesiaLab and *Netica* are the next best performance alternatives. Once again, the reader can look at the contributions by criteria window to gain further insight into the contributing factors towards the final decision scores of these tools.

4.5.7 Discussion of GOTS Tools

4.5.7.1 SAIC

SIAM

Compared to the other commercial Bayesian tools, *SIAM* ranked 5th among the nine alternatives. Following are the reasons for its relatively low decision score:

- Input Manipulation: One of the major drawbacks of *SIAM* is that it does not support Bayesian Inferencing. Bayesian Inferencing is where the user, upon collection of more information about certain nodes in the net, enters the information (evidence) into the net. Based on the new information entered, the tool updates the probabilities of other nodes in the network. Some of the other features that *SIAM* does not address the learning of probabilities from a sample set and learning of the structure of the net from a database. These features are useful to have if the end user wants the tool to work with the existing data.

- Performance & Extensibility: In this category, *SIAM* ranked low because of the emphasis placed on the language used to develop the computational engine and the Graphical User Interface (GUI). The preferred language was C/C++ and *SIAM* was developed in Java. The lack of an Application Program Interface (API) for *SIAM* also contributed to its low score.

4.5.7.2 Charles River Analytics

Organizational & Cultural Criteria for Adversary Modeling - Bnet2000

OCCAM is a decision aiding system that helps build models by employing Bayesian Network Techniques, Rule Based Reasoning and Social Net Analysis.

The following steps outline how these techniques work together in building a decision aiding system. (Note: This high level information is gathered from talking to the developers of *OCCAM* and not from using the tool or reading any technical description of the tool):

- An Entity is a person or organization that the user is interested in modeling. An Entity has attributes.
- Application data is collected for the attributes of the entity.
- Rules are constructed using this application data and also the data is further analyzed using Social Net Analysis tools.
- The next step is to build a Bayesian net using *Bnet2000. Bnet2000* is an in-house Bayesian tool. Currently, *Bnet2000* does not support automatic construction of the Bayesian net from the data available. So the net is built by domain experts who understand the causal relationships between the nodes. Beliefs for the nodes are recorded based on the results from rule based reasoning, social net analysis of the application data and other proprietary techniques.

As *OCCAM* employs more than Bayesian Nets, we felt that it needs to be addressed separately and not be included in the list of alternatives being rated. However, we did include *Bnet2000* to the list of alternatives. From the decision scores it can be seen that it did not rank high. The reason for low scores is partly due to the fact that we did not have an evaluation/trial copy to work with and had to entirely depend on the information from the questionnaire. Also, it might be that *Bnet2000* did not address some features due to the fact that it is being used together with other AI techniques, where the capabilities from these techniques compensated for the features that *Bnet2000* lacks.

Based on the information gathered for *OCCAM*, it can be said that it seems to be addressing the domain specific needs of the customer. It also employs all the techniques that the customer is planning to apply to build a decision support system that helps model the influences impacting human behavior.

Sample/Grade

Sample is an architecture that provides support to the user to build models that apply Artificial Intelligence (AI) techniques. Some of the techniques supported are Bayesian Nets, Fuzzy Logic, Genetic Algorithms, and Expert Systems etc. Grade is a GUI development environment that helps the user build a model by combining the techniques provided by *Sample* and to later simulate it. At SRA, we haven't had a chance to work with this architecture/environment tool. From the information we collected, we believe that it might be useful to the customer if they plan to employ multiple AI techniques other than Bayesian Nets.

4.5.7.3 AFRL/Metrica, Inc.

Evaluation of Cross-Cultural Models for Psychological Operations: Cross-Cultural PSYOP Decision Support System

This system was developed as a part of a study performed by Metrica, Inc., for Air Force Research Laboratory. The study was done in three phases, where the last phase led to the development of the *Cross-Cultural PSYOP Decision Support System* (*CCP-DSS*). Refer to [2] (at end of Section 4) for the details of the study.

The *CCP-DSS* is a web-based system that merges several databases related to PSYOP supporting objectives included in the system. These data include the associated influencing factors for the objectives, background information about the individual factors and response data from previous users, detailing their assessments of factor influence and probable target audience response to specific hypothetical PSYOP scenarios [2].

This DSS was not considered as one of our alternatives because of the following:

- Employs SMART technique and not Bayesian methods. We are primarily focused on tools that employ Bayesian techniques.
- It is a Knowledge-driven DSS. These are systems that have specialized-problem expertise. The system contains knowledge about a specific domain and uses this knowledge to aid decision process of the user. The alternatives we are considering are not Knowledge-driven DSS.

Although the tool is not applicable as one of the alternatives, the feature of building a database that contains data supporting PSYOP objectives and helping the user based on this information is a very useful technique. This technique can be applied to the Bayesian tools to help the user determine the a-priori probabilities.

4.5.8 Future Extensions

For the evaluation process of the tools, we did not consider features of the tools that were in the process of being implemented. However, we feel that it is important to mention these extensions so that the customer can decide accordingly – to go with the current optimal tool or to wait for a tool (that is relatively cheap) and will have certain features implemented in their next versions. In general, with the commercial tools, tool vendors were very flexible regarding extension of their feature set to accommodate customer needs. Table 12 summarizes the tools and future extensions in their next releases. This information was gathered from talking to the respective tool representatives.

Table 12. Planned Extensions for Some Vendors

Tool Name	Extensions
Netica	Availability of OpenModel Format and Structure Learning
BayesiaLab	Availability of Decision Nodes and Conflict Analysis
Ergo	Sensitivity Analysis can be performed via GUI

4.5.9 "Ease of Use" Evaluation

4.5.9.1 Industry Standard Techniques

The usability evaluation was conducted on the four demo version applications that ranked highest in the functional evaluation: *Analytica*, *Netica*, *Hugin*, and *BayesiaLab*. Three primary approaches to usability assessment were considered in determining an evaluative methodology for this project: 1) heuristic evaluations with usability guidelines, 2) cognitive walkthroughs, and 3) usability testing. The selected methodology included elements of all three techniques. Testing was conducted by a human factors researcher; the results were collapsed and loaded into the decision support tool to obtain a usability ranking. A short discussion of the three methods, followed by a discussion of the selected evaluation methodology, the ranking criteria, and the evaluation results follow.

Heuristic evaluations employ general usability guidelines (testable design principles) that focus attention on design areas that have historically proven sources of user difficulties. A good heuristic evaluation attempts to balance consistency (maintaining standardization for ease of use) and complexity (allowing variation to support expert users) and assess the application in the context of its expected use. Table 13 lists ten commonly accepted usability guidelines, derived by factor analysis of 249 usability problems across 11 projects [6]. Cost/benefit analyses have shown that the most effective results are obtained using four evaluators for a comprehensive result [7]. Problems with this method involve assessing how to deal with trade-offs and how to apply guidelines judiciously within the current context.

Table 13. Ten Commonly Accepted Usability Guidelines

Visibility of system status. System provides status feedback to user.	Recognition rather than recall. System keeps all options and support for actions visible.
Match between system & the real world. System employs familiar terms and concepts.	Help recognizing, diagnosing & recovering from errors. System assists rather than confuses.
User control & freedom. System offers quick exit path from errors and undo/redo function.	Flexibility & efficiency of use. System offers accelerators for expert users while aiding novices.
Consistency & standards. System uses consistent terms and visualizations.	Aesthetic & minimalist design. System communications are relevant and cogent.
Error prevention. System design helps user avoid errors.	Help & documentation. System helps are concise, clearly stated, task-focused, and searchable.

Cognitive walkthroughs employ a set of representative tasks; the evaluator performs the tasks, step-by-step, and documents each system interaction. In a formal cognitive walkthrough, the evaluator uses pre-prepared forms to document the typical user's specific goals, tasks, and knowledge at each step. How the system interface appears and how it changes in response to user actions is also documented. This form of evaluation is based on the psychology of inexperienced users and evaluates the system for ease of learning and support for exploratory learning. Identification of the psychological bases for user difficulties (e.g., confusion due to inadequate function labeling or error due to insufficiently explained input options) also indicates possible solutions. Testing is based on four main questions: 1) Will the users try to achieve the right effect? 2) Will the users notice the correct action is available? 3) Will the user associate the correct action with the desired effect? and 4) If the user performs correctly, will the user realize progress is being made toward task accomplishment? The problems with cognitive walkthroughs center around three points. They require in-depth knowledge of the task domain for adequate test task selection. They are time-consuming; strict protocols and copious documentation require time. They are also susceptible to a low-level problem bias; concentrating at the keystroke level, it is difficult to see the high level problems that yield higher payoffs.

Usability testing involves the development of empirical test plans that allow observers to assess system support to real users in realistic scenarios, performing real-world tasks. Observers document user behaviors and evaluate performance effectiveness; they also may employ a "thinking aloud" protocol to access user thought processes. Interviews and questionnaires are also techniques used to capture user impressions. Studies support three users as a cost effective number of test subjects [7]. Problems with this method involve the development of appropriate scenarios and tasks, difficulties with subject availability, and interpretation of results from different user expertise levels.

4.5.9.2 Integrated Approach

This project did not support the full-scale employment of any of the foregoing techniques. Neither multiple domain experts nor multiple usability experts were available; time considerations were also a limiting factor, constraining both test duration and model task development. To meet project needs, a rapidly obtainable, high-level usability evaluation was created, drawing on elements in all three techniques. The test plan created for this project was based jointly on two industry standard heuristics, Xerox Corporation's *Usability Analysis and Design, Heuristic Evaluation: A System Checklist* (an expansion of the ten factors identified earlier) [8] and DoD's *Defense Information Infrastructure Common Operating Environment (DIICOE) User Interface System Checklist* [9]. The two checklists were examined for overlaps and edited accordingly. A preliminary examination of the applications indicated that many of the low-level detailed checks were either not problematic or subordinate in importance to larger issues; the combined checklist was filtered for non-issues and subordinate issues to leave the items likely to represent critical design concerns. The resulting list incorporated "bellwether" issues from all of the major categories (Table 14). The matrix in Attachment 9 offers more detail.

Table 14. List of Significant Evaluative Issues

No.	Issue	No.	Issue
1	**User/Computer Interaction**	4b	**Error Prevention/Recovery**
1a	**Icons/Push Buttons**	4c	**System Shutdown**
1b	**Menus**	5	**Flexibility/Efficiency/Legibility**
1c	**Windows/Dialog Boxes**	6	**Other Functionality**
1d	**Feedback**	7	**Visualizations**
2	**Consistency/Standards**	8	**Print Control & Reports**
2a	**Windows Metaphor**	9	**Help/Documentation**
2b	**Common Look & Feel**	9a	**Type of Online Help file**
3	**System Status Visibility**	9b	**Information Organization**
4	**Errors, Error Prevention & Recovery**	9c	**Accessibility of Language**
4a	**Errors**	9d	**Tutorial**

Although grouped somewhat differently to better correspond with potential problem areas in the applications, all but one of the ten factors were explicitly reviewed. "Match between system and real world" was not considered truly appropriate to the current evaluation. The terminology for Bayesian statistics and Bayesian net-building was domain-specific; in this case it seemed more realistic to check documentation for clarity of language and concept explanations. The lead issues (each with more detailed subcriteria) were incorporated in a matrix; each application was reviewed separately and results and comments were noted.

The selected approach integrated elements from the other usability evaluation techniques as well. The concepts of test tasks and bi-level analysis (low level data entry as well as more high-level functional organization and task

support issues) were drawn from cognitive walkthroughs and the documentation structure of the effort, from observational documentation methods. In the absence of a formal test model, three methods were used. First, in keeping with the psychological orientation of the heuristic evaluation, the evaluator tried to exercise baseline network construction and compilation functions as a novice, looking for identifiable tools and intuitive processes. Difficulties were noted and assessed. Second, the evaluator attempted to build a small network and compile it. Third, the evaluator opened the Asia model (a diagnostic model included with each application as an example) and systematically altered it to observe the system response. All results were integrated in the relevant sections of the evaluation matrix.

The initial documentation effort was not set up to be hierarchical. However, after reviewing the results, it was determined that MCDA AHP could be applied to the usability criteria as well. Accordingly, the documentation was examined for trends and for uniform scores. Where all applications were rated uniformly acceptable, the criterion was dropped from further consideration. Where all applications were rated uniformly unacceptable, the results were analyzed and the criterion was expanded appropriately to try to capture the cause of the problem. Trends were evaluated for contributory factors and the criteria list was amended to probe those issues. The amended list was decomposed so each criterion could be weighted appropriately. As all the factors in the final criteria list were considered critical to good user interface design, weights were distributed relatively equally across the criteria. The final evaluative criteria were reassessed for each program and any changes in results were integrated into both the initial and final criteria sets.

Table 15. Final Evaluative Criteria List

1. User Support
   - **Dialog Box Help**
   - **Find Function**
   - **Wizards**
   - **Tutorial**
     - Example Scenarios
     - Level of Complexity
     - Process Orientation
     - Language
     - Key Word Search Capability
   - **Help**
     - Language
     - Glossary
     - Searchable Index
     - TOC Organization
     - Completeness
2. Error Management
   - **Validation Errors**
     - Warnings
     - Explanations
     - Automatic Repair Function
   - **Input Errors**
     - Warnings
     - Explanations
   - **System & Fatal Errors**
3. Efficiency Factors
   - **Rapid Input/Manipulation Methods**
     - Repetitive Action Capabilities
     - Align Tool
     - Reverse Links Tool
   - **Windows Common Look/Feel**
   - **Comprehensive Node Representation**
   - **Model Description**
4. Visualizations
   - **On Screen**
     - Tables & Networks
     - Graphs
     - Text
     - Error Logs
   - **Printing**
     - Page-break Preview
     - Scale-to-Fit Capability
     - Completeness

The final criteria list (Table 15 above) excluded most Windows Metaphor/Common Look and Feel issues. There were few problems with the Windows metaphor or standardization of application elements: it was collapsed to a single entry under Efficiency Factors. Feedback was not an issue either because it was uniformly adequate or uniformly untestable with the available models. Icons were not a significant factor in user problems. Major trends were in application documentation and internal support to task accomplishment—both judged critical application usability. Error messages offered some problems; system design was insufficient to eliminate errors, but without a more detailed model it was difficult to probe further. Print control and print capabilities were insufficiently supported; the total number of visualizations each application offered were difficult to document and display. Efficiency factors were less critical to task completion, but certain features (e.g., reverse links and rapid netbuilding tools) would be very important to large network construction. The weighted evaluation criteria and AHP results are discussed in the sections below.

4.5.9.3 Ease of Use Results (Tables 16-27)

User Support Evaluation Criteria

Table 16. Definitions for User Support Criteria

User Support	Description
Dialog Box Help	Offers interpretative help filling in data fields from within the dialog box.
Find Function	Permits modeler to search for a specific node in a large network.
Wizards	Facilitates performing routine or specialized action sequences.
Tutorial	
Example Scenarios	Tutorial provides example scenarios for all supported utilities.
Level of Complexity	Scenarios have sufficient complexity to exercise all functions.
Process Orientation	Tutorial language displays a process rather than a procedural orientation (step-by-step instructions rather than overview).
Language	Language is simple, direct, and uses as little jargon as possible.
Key Word Search Capability	Tutorial has internal keyword search capability to support finding specific instructions.
Help	
Language	Language is simple, direct, and uses as little jargon as possible.
Glossary	Help includes a glossary of terms to facilitate understanding of technical terminology.
Searchable Index	Help includes a searchable index of all key terms.
TOC Organization	Table of Contents is organized to support reasonable sequence of modeler activities (either working with or creating networks).
Completeness	All functions and required inputs are completely explained in Help. Tutorials offer supplementary method of obtaining information.

Table 17. Rank Structure for User Support Criteria

User Support	Rank Definition
Dialog Box Help	0= No dialog box Help and can't open Main Help w/dialog box open. 25=No dialog box Help but can open Main Help w/dialog box open. 50=Dialog box Help links to Main Help table of contents. 75=Dialog box Help links to appropriate topic in Main Help. 100=Dialog box Help opens popup explanations/instructions.
Find Function	Y= 100 N=0
Wizards	Y= 100 N=0
Tutorial	
Example Scenarios	75 = Most 100= All **Note**: Can't tell if all functions are included in this level of audit.
Level of Complexity	Basic functions=50 Complex functions=75 All functions=100 Note: Can't tell if exercises all functions with this level of audit.
Process Orientation	Y= 100 N=0
Language	Clear Language=100 Somewhat Clear=50 Not Clear=0

User Support	Rank Definition
	Whole document=100
	By Chapter=75
Key Word Search Capability	By Page=25
Help	
	Clear Language = 100
	Somewhat Clear=50
Language	Not Clear=0
	Y= 100
Glossary	N=0
	Y=100
	Some search capability=50
Searchable Index	N=0
	Y= 100
TOC Organization	N=0
	Complete=100
	Reasonably Complete=75
	Somewhat Complete=50
Completeness	Not Complete=25

User Support Results

Table 18. Results for User Support Criteria

User Support	*Analytica*	*Netica*	*Hugin*	*BayesiaLab*
Dialog Box Help	25	50	25	0
Find Function	100	100	0	100
Wizards	0	0	100	100
Tutorial				
Example Scenarios	100	50	100	50
Level of Complexity	100	50	100	50
Process Orientation	100	0	100	100
Language	100	100	50	100
Key Word Search Capability	100	75	75	100
Help				
Language	100	100	50	0
Glossary	100	0	0	0
Searchable Index	100	100	0	50
TOC Organization	100	100	0	0
Completeness	75	50	25	50

All applications were distinctly lacking in context-sensitive Help, a very important user support function. An ideal software application provides substantive assistance with all decision points; this includes directions for how to fill in all data fields. The criterion Recall vs. Recognition, one of the ten standard usability guidelines, stresses the importance of keeping support information visible; this is an important error avoidance technique. In the four applications evaluated the major need for context-sensitive Help was in dialog box interactions; therefore, the evaluation refers specifically to Dialog Box Help.

Dialog boxes require the user to fill in data fields to accomplish a task. While it would be impractical to keep all data field descriptions and input criteria/constraints visible, it is very possible to use hover popups or rightclick responses to provide the necessary support. The worst case scenario was shown in *BayesiaLab*, where not only is there no internal help, but the main Help function cannot even be accessed without closing the dialog box (a clear case of recall dependence).

Three of the four applications included a Find function, permitting users to search for and locate specific nodes by name; no capability was identified in *Hugin*. This feature could become important in large, complex network constructions. In contrast, only *Hugin* and *BayesiaLab* offered any kind of Wizards—*Hugin*, for setting up structure and batch learning and *BayesiaLab*, for file importation. Wizards are interactive help utilities that guide users through potentially complex tasks, allowing novice users to perform at higher levels of expertise. Often implemented as a sequence of dialog boxes that prompt users to fill in required details, properly documented wizards are an excellent way to support multiple levels of user expertise.

The Help and Tutorial tools are critical to usability. Help documentation ideally is designed around its potential use, either as an on-line support or as a print document; readability on-line is not the same as readability in print. On-line Help is very important because it answers user questions during task accomplishment. Printable manuals are very important because they allow the user to study the application (and by extension, task performance) for extended periods without access to a computer. Tutorials (which also can be on-line or printed) walk users through example tasks, increasing their expertise. Information in tutorials does not substitute for Help. When users want answers, they want them immediately, and they often cannot afford to search through linear tutorial presentations to obtain critical information. Therefore, every user action should be supported by the main Help. Tutorials should provide step-by-step instructions for both simple, novice-level tasks and complex, expert-level activities. Both the main Help and the tutorial should be organized around task performance, beginning with frequently performed actions, continuing progressively through less frequent activities. The language in all documentation should be clear, concise, and understandable by all levels of user. Domain-specific terms should be explained in context and in a glossary. On-line Help and tutorials should support key word searches.

BayesiaLab suffered from very poor translation in its on-line Help, rendering it almost incomprehensible; its tutorial was much more understandable, however. *Hugin* used HTML files for both its on-line Help and its tutorial, rendering searches difficult. It also used highly technical language in places, failed to provide a glossary, offered no index for rapid navigation, and its table of contents was organized around alphabetized menu and toolbar items rather than tasks. Finding task support through *Hugin* was extremely difficult. However, *Hugin*'s tutorial was very good in its provision of introductory material and representative

task instructions. *Netica*'s HTML-based tutorial was also difficult to search and displayed a procedural rather than a step-by-step process orientation (since it is still under development it is unfair to rate its completeness). None of the main Helps appeared able to stand alone; task accomplishment required lengthy searches of both Help and tutorials; *Hugin* was worst as its on-line Help appeared to lack much critical information. *Analytica* provided by far the most detailed documentation (the manual is 548 pages), including a glossary, index, error messages and a function list; their Help and tutorials were PDFs (making them both searchable and printable) with multiple examples of varying complexity and a process orientation throughout. *Analytica*'s Help provides functional information while its tutorial steps the user through building representative models. The only weakness encountered was an occasional need to use the tutorial to supplement Help—but required information was readily available.

Efficiency Factors Evaluation Criteria

Table 19. Definitions for Efficiency Factor Criteria

Efficiency Factors	Description
Rapid Input/Manipulation Methods	
Repetitive Action Capabilities	Facilitates rapid net-building by allowing user to create multiple nodes and connectors.
Align Tool	Allows modeler to align multiple nodes.
Reverse Links Tool	Allows modeler to reverse direction of the links between selected nodes.
Windows Common Look/Feel	Uses a Windows metaphor and provides standard functions in standardized positions, stable tool bars, easily interpreted icons, hover descriptions of icons.
Comprehensive Node Representation	Node network and node attributes and conditional probabilities can be displayed and edited on the same screen.
Model Description	Permits modeler to describe rationales and assumptions to aid others using the model.

Table 20. Rank Structure for Efficiency Factors Criteria

Efficiency Factors	Rank Definition
Rapid Input/Manipulation Methods	
Repetitive Action Capabilities	Tool available=100 Method available but takes 2 hands=75
Align Tool	Y=100 N=0
Reverse Links Tool	Y=100 N=0
Windows Common Look/Feel	Very Consistent=100 (3 Ns or fewer in categories on master data collection sheet) Somewhat Consistent=75 (5 Ns in categories on master data collection sheet) Seldom Consistent=25 Not Consistent=0

Efficiency Factors	Rank Definition
	Very Consistent=100 (3 Ns or fewer in categories on master data collection sheet)
	Somewhat Consistent=75 (5 Ns in categories on master data collection sheet)
	Seldom Consistent=25
Comprehensive Node Representation	Not Consistent=0
	Y=100
Model Description	N=0

Efficiency Factor Results

Table 21. Results for Efficiency Factors Criteria

Efficiency Factors	*Analytica*	*Netica*	*Hugin*	*BayesiaLab*
Rapid Input/Manipulation Methods				
Repetitive Action Capabilities	100	100	75	100
Align Tool	100	100	100	0
Reverse Links Tool	0	100	100	0
Windows Common Look/Feel	75	75	100	100
Comprehensive Node Representation	25	50	100	100
Model Description	0	100	0	0

All of the applications had repetitive action capabilities and all but *BayesiaLab* had an align tool; both capabilities speed model building—important when building very large networks. *Netica* and *Hugin* supported reversing links, another useful capability to speed the network-building process. A familiar Windows-like environment is also a factor that speeds task completion; all tools were acceptable, but *Analytica* used data field screens with cells and dropdown boxes for some of its data entry and these were harder to interpret and required extra cursor movements. The data cells were particularly confusing, as the default view showed a single cell and the user had to select that cell and hit the Enter key to add cells. This was explained in the tutorial, but was not supported in the data screen itself. Figure 19 shows *BayesiaLab*'s composite dialog box that allows the user to rapidly enter all supporting node data.

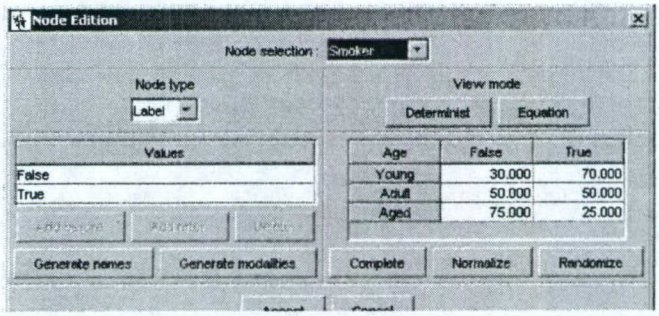


Figure 19. *BayesiaLab* composite dialog

Error Management Evaluation Criteria

Table 22. Definitions for Error Management Criteria

Error Management	Description
Validation Errors	Conditional probability errors (failure to sum to 1) and cyclic errors (node connections form cycle).
Warnings	Program warns user an error has occurred via visible or audible signals.
Explanations	Warning includes an explanation of the location and type of error.
Automatic Repair Function	Program can be set to repair probability errors automatically (automatically normalizes data).
Input Errors	Errors in types of information input into data fields.
Warnings	Program warns user an error has occurred via visible or audible signals.
Explanations	Warning includes an explanation of the location and type of error.
System & Fatal Errors	Warns of system & insufficient memory errors.

Table 23. Rank Structure for Error Management Criteria

Error Management	Rank Definition
Validation Errors	
Warnings	Message Box=100 Symbol w/popup=50
Explanations	Explains probability & cycles=100 Explains cycles only=50 Must set to normalize=100 Warns will automatically normalize=50
Automatic Repair Function	Automatically normalizes=0
Input Errors	
Warnings	Boxed text warning=100 Symbol=75 Message pops up=100
Explanations	Takes 2 hands to display message=50 Y=100
System & Fatal Errors	N=0

Error Management Results

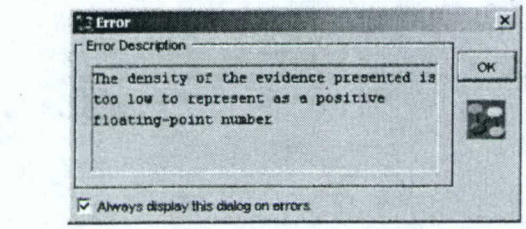
Table 24. Results for Error Management Criteria

Error Management	*Analytica*	*Netica*	*Hugin*	*BayesiaLab*
Validation Errors				
Warnings	100	100	100	100
Explanations	100	100	50	50
Automatic Repair Function	50	100	0	0
Input Errors				
Warnings	100	100	100	75
Explanations	100	100	50	50
System & Fatal Errors	100	0	0	0

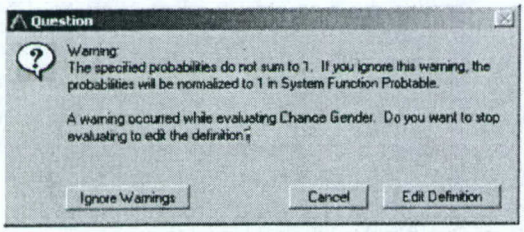
This set of criteria, while very important to the user, was not thoroughly investigated. Factors involved in this decision included the variation in functions supported by the applications (e.g., *Analytica* supported dynamic but not static cyclic dependencies, whereas *Netica*, *Hugin* and *BayesiaLab* flag and prohibit directed cyclic dependencies) and the lack of a representative, rigorous test model. The standard example, "Asia", included with each program, didn't fully exercise the error management capabilities of the systems.

All applications prohibited cyclic errors with an accompanying explanation (*Analytica*'s warning offered an alternative means of defining cycle nodes to make the cycle dynamic). Probability table error management was handled in three different ways: *Analytica* warned that it would normalize the illegal entry if directed to proceed with compilation, *Netica* simply flagged probability table errors, whereas *Hugin* and *BayesiaLab* automatically normalized values. Automatic normalization was judged a fault in this evaluation because it denied user control and hid the potential introduction of erroneous values from the user.

Input errors were the most difficult to evaluate because the evaluator, with only limited knowledge of Bayesian net building and a limited test model, did not test all possible error conditions. Evaluation in this section was based on whether the system provided input error notification, how readily visible the warning was, the clarity of explanation and provision of instructions to repair the error. All systems provided some form of error message (*BayesiaLab* used a warning symbol that required effort to open); none provided specific instructions along with their explanations. This was considered a serious lack, given the complexity of the network-building task. See Figure 20 for sample messages.


Error
Error Description
The density of the evidence presented is too low to represent as a positive floating-point number
OK
Always display this dialog on errors

Hugin Error Message notes an evidence input error for a continuous chance node


Question
Warning:
The specified probabilities do not sum to 1. If you ignore this warning, the probabilities will be normalized to 1 in System Function Probtable.
A warning occurred while evaluating Chance Gender. Do you want to stop evaluating to edit the definition?
Ignore Warnings
Cancel
Edit Definition

Analytica Error Message notes a probability input error, offering an automated fix or a chance to edit the input.

Figure 20. Sample error messages

Visualizations Evaluation Criteria

Table 25. Definitions for Visualizations Criteria

Visualizations	Description
On Screen	
Tables & Networks	Displays node network and associated conditional probability tables simultaneously.
Graphs	Displays node information in different graph formats (bars, line graphs, etc.
Text	Displays text descriptions of node network.
Error Logs	Displays user's session error log in text box.
Printing	
Page-break Preview	Permits the modeler to see where the page breaks will occur in the network or table and adjust page setup accordingly.
Scale-to-Fit Capability	Permits the modeler to scale the network to fit the page.
Completeness	Prints nets, tables, graphs, text reports and error logs (or some subset).

Table 26. Rank Structure for Visualizations Criteria

Visualizations	Rank Definition
On Screen	
Tables & Networks	
Graphs	Each of the On Screen attributes rates 25 if Y and 0 if N. All four attributes sum to an On Screen score of 100.
Text	
Error Logs	
Printing	
Page-break Preview	Y=100 N=0
Scale-to-Fit Capability	Y=100 N=0
Completeness	Prints everything it shows=100 (includes reports) Prints tables, network & text=75 Prints tables & network=50

Visualizations Results

Table 27. Results for Visualizations Criteria

Visualizations	*Analytica*	*Netica*	*Hugin*	*BayesiaLab*
On Screen				
Tables & Networks	25	25	25	25
Graphs	25	25	25	25
Text	0	25	0	25
Error Logs	0	25	0	0
Printing				
Page-break Preview	100	100	0	0
Scale to Fit Capability	100	0	100	100
Completeness	100	100	50	75

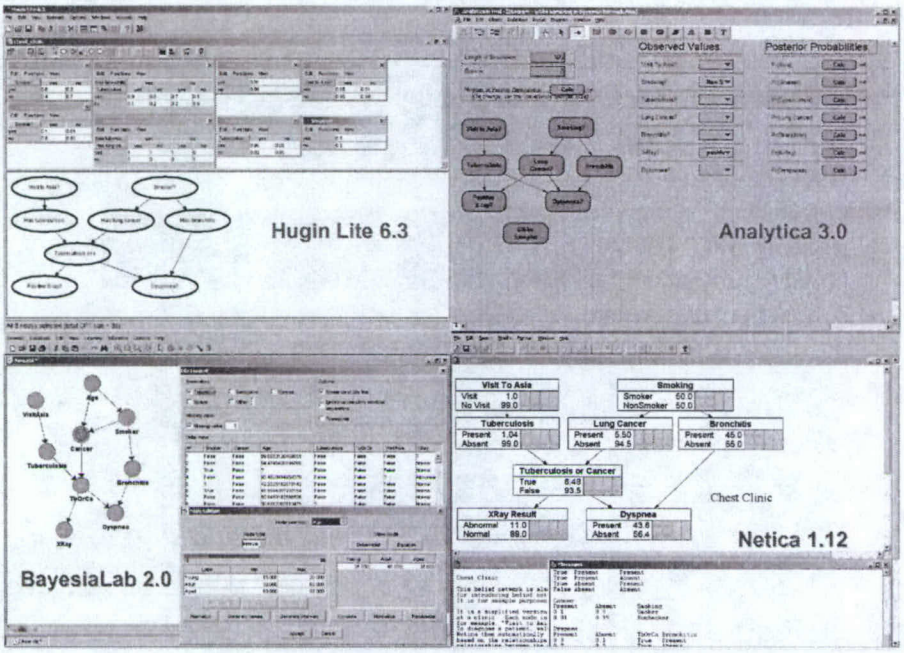


Figure 21. Summary visualizations from each application

Visualizations were divided into visual representations on screen and print capabilities. The applications varied widely in the representations offered and the forms taken. In Figure 21 above, *Analytica*'s summary visualization was programmed, while the others were available as menu options. The quality of the visualization varied considerably. *Analytica* did not support simultaneous representations of their network node maps, attribute charts, and conditional probability data. In contrast, *BayesiaLab* used an easily read and understood composite attribute/conditional probability table, visible with the node map, and *Netica* even displayed the network description and error log in frames. The ability to add a network description to aid other users was seen only in *Netica* and *BayesiaLab*; error logs (important to users learning the system) were available only in *Netica*. Print capabilities ranged from *Hugin*'s restriction to networks, node attribute, and probability tables only to *Analytica* and *BayesiaLab*'s ability to print all visualizations and report results. Of the four applications, only *Hugin* had no sensitivity analysis capability.

4.5.9.4 AHP Results

As noted previously, the applications varied greatly in their intended use as well as their capabilities. The results of the AHP analysis (Figures 22 and 23) showed *Netica* the most user friendly in terms of user support, efficiency of entry, error management, and supported visualizations; *Analytica* was a close second with the other two applications ranking significantly lower in ease-of-use.

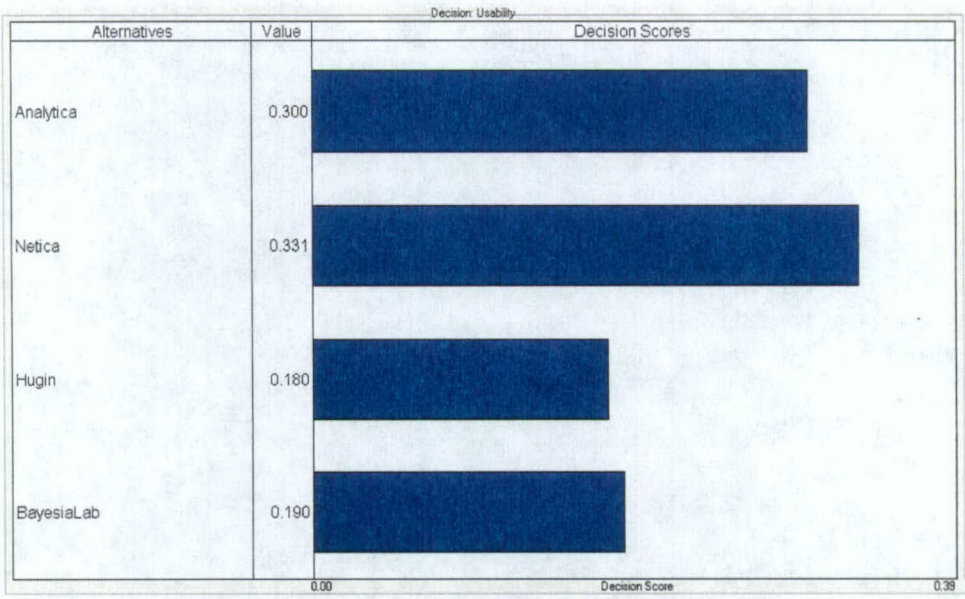


Figure 22. Usability Factors Decision Score

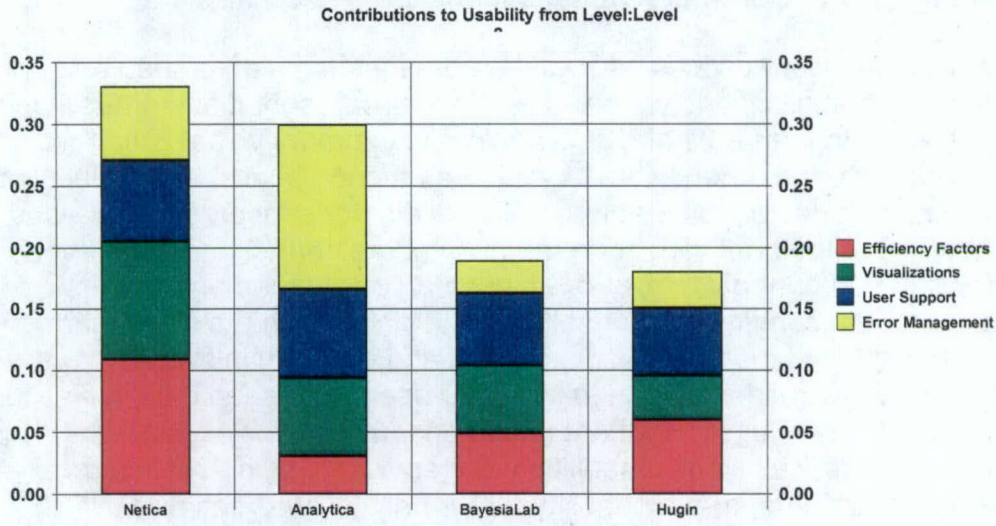


Figure 23. Usability Factors by Criteria

Section 4.5 References:

[1] InfoHarvest Criterium® DecisionPlus® 3.0 User's Guide
[2] Final Technical Report, Cross-Cultural PSYOP Decision Support System (DSS): Development of Software Application for an Automated Prototype
[3] Report of a Market Survey and Research on Time Line Analysis Tools
[4] Charniak, E. "Bayesian networks without tears". *AI Magazine*, 12(4), 1991
[5] Baecker, R., Grudin, J., Buxton, W., & Greenberg, S. (Eds.). Readings in Human-Computer Interaction. 2nd ed. Morgan Kauffman, 1995
[6] Nielsen, J. Heuristic Evaluation. In J. Nielsen and R. Mack (Eds.), *Usability Inspection Methods*. Wiley & Sons, 1994

[7] Nielsen, J. & Landauer, T. A Mathematical Model of the Finding of Usability Problems. *Proceedings of INTERCHI '93*, ACM, 206-13, 1993.
[8] Pierotti, Deniese. Heuristic Evaluation: A System Checklist. In *Usability Analysis and Design*. Xerox Corporation, 1995.
[9] Department of Defense. *Defense Information Infrastructure Common Operating Environment (DIICOE) User Interface System Checklist.*

5 RECOMMENDATIONS

5.1 Text Mining Tools

As mentioned previously, we are considering three categories of tools – Text Mining, Investigative Analysis, and Bayesian tools that would help an analyst with his/her task. However, as the emphasis of this study was on Bayesian modeling tools, we have not had a chance to do an in-depth evaluation of text mining and investigative analysis tools. SRA, a regular user of vendor products, has gathered information from sources that do in-depth study of these tools.

For text mining tools, we relied on market research done by SRA. Table 28 lists well known tools and vendors in different categories of text mining.

Table 28. Text Mining Tools

Technique	Tool Name	Website
Categorization of documents	Autonomy	http://www.autonomy.com/Content/Technology/
	Convera	http://www.convera.com/Products/index.asp
	Entrieva	http://www.entrieva.com/entrieva/index.htm
	InXight	http://www.inxight.com/
	Mohomine	http://www.mohomine.com/
	Stratify	http://www.stratify.com/
	Verity	http://www.verity.com/products/index.html
Summarization	Copernic	http://www.copernic.com/en/products/summarizer/index.html
	InXight	http://www.inxight.com/

5.2 Social Network Analysis Tools

For social network analysis tools, the recommendation is based on the results from a detailed survey done for MITRE Corporation. In this report, i2's *Analyst Notebook Version 6* was the first recommendation and the next recommendation was Visual Analytics *VisuaLinks*. For further details regarding the criteria used, other tools evaluated and generation of results, refer to [3] (end of Section 4), included as Attachment 8 to this report.

5.3 Modeling Tools

5.3.1 Performance

From Section 4.5.6, it can be seen that *Hugin* ranks as the optimal Bayesian tool among all the ranked alternatives. The next best alternatives are *BayesiaLab* and *Netica*.

Most of *Hugin*'s high decision score can be attributed to the number of features it supported in the category of Input Manipulation and the fact that criteria Input Manipulation was given the maximum weight towards the final goal of choosing an optimal tool.

BayesiaLab has excellent design sense from a usability standpoint. Though there are some "ease of use" problems, they should be relatively easy to fix. Both *Hugin* and *BayesiaLab* personnel were very helpful and receptive to making changes and adding features in response to specific queries and customer requests (in fact the *BayesiaLab* folks have already made some changes/updates in response to queries from this study).

Netica and *BayesiaLab* representatives are already addressing some of the performance issues that led to their ranking below *Hugin* (see Table 12). With the addition of these planned extensions, it is likely that the performance rankings for *Netica* and *BayesiaLab* will improve.

SIAM is the only GOTS tool that we analyzed in detail, for reasons described in Section 4. One of the major drawbacks of *SIAM* is that it does not support Bayesian Inferencing. Other features that *SIAM* does not address: the learning of probabilities from a sample set and learning of the structure of the net from a database. These features are useful if the end user wants the tool to work with existing data. In Performance & Extensibility, *SIAM* ranked low because of the emphasis placed on the language used to develop the computational engine and the Graphical User Interface (GUI). The preferred language was C/C++ and *SIAM* was developed in Java. The lack of an Application Program Interface (API) for *SIAM* also contributed to its low score. All that said, *SIAM* does have performance features that will be useful for NASIC in the near term.

Based on the information gathered for *OCCAM*, it can be said that it seems to be addressing the domain specific needs of the customer. It also employs all the techniques that the customer is planning to apply to build a decision support system that helps model the influences impacting human behavior.

Sample might be useful to NASIC/BPB if they plan to employ multiple artificial intelligence techniques (in addition to Bayesian Nets).

Although Metrica's PSYOP DSS tool is not applicable as one of the ranked alternatives (does not use Bayesian methods), the feature of building a database

that contains data supporting PSYOP objectives (and helping the user based on this information) *is* a very useful technique. This technique can be applied to Bayesian tools to help the user determine the a-priori probabilities.

5.3.2 Ease of Use

Where *Hugin* and *BayesiaLab* were the top modeling tools from a performance perspective, *Netica* and *Analytica* stood out from those two in usability. *Netica* rated most "user friendly" in terms of user support, efficiency of entry, error management, and supported visualizations. *Analytica* was a close second in all these categories, with the *Hugin* and *BayesiaLab* ranking significantly lower in ease of use.

SRA continues to receive information from all these companies. As we get more information, we will update our AHP analysis to ensure we have accurately modeled them and get the correct relative ranking. As we get results, we will provide them to the customer. However, from both a performance and a usability perspective, it would be far preferable to validate results from this study against a representative sample problem or scenario.

5.3.3 Cost

Table 29 summarizes the cost per single license, quantity licenses, and site license of the top five modeling tools. As some of the tools prices are listed in Euros, refer to http://www.x-rates.com/calculator.html for an equivalent price in Dollars.

Table 29. Cost Summary.

Tool	Pricing Structure
Hugin	(GUI and API Priced) 1 License – 6300 Euros 2 Licenses – 8390 Euros 5 Licenses – 10,465 Euros 10 Licenses – 12,550 Euros Site License – 16,785 Euros
BayesiaLab	(GUI and API Priced) 1 License – 3450 Euros 5 Licenses – 10,350 Euros 10 Licenses – 17,250 Euros 50 Licenses – 43,125 Euros
Netica	GUI - $585 per License, API - $685 Note 1: Site licenses available for 5 times as much. Note 2: API embedded is $20 to $175 depending on the volume.

Tool	Pricing Structure
Analytica	Professional - $1295 Enterprise - $2495 Analytical Decision Engine - $6000 Note 1: Website (Attachment 3) gives comparison of features of these different versions) Note 2: 15% discount for 10+ Licenses Note 3: 25% discount for 50+ Licenses
SIAM	All US gov't agencies hold a license to use *SIAM* for gov't purposes (just need federal ID)

Complete cost information for the rest of the evaluated tools can be found in the *"General Features"* worksheet in Attachment 3.

6 CONCLUSION

6.1 NASIC's Investment in Analytical Capabilities

Many viable text/data mining options are available to NASIC/BPB. SRA is very familiar with NetOwl, and has used it for a variety of applications. However, other options were presented in Section 5.

From discussions with experts in the field of Social Network Analysis, we were referred to a Mitre Corporation report (Attachment 9) that ranked i2's Analyst Notebook Version 6 at the top of the list of these capabilities. The next best capability recommendation was Visual Analytics VisuaLinks.

Based on the results of this study, NASIC/BPB has at least five viable options to meet mission modeling requirements: *Hugin*, *BayesiaLab*, *Netica*, *Analytica*, and *SIAM*. Unfortunately, the tool that ranked best in terms of performance (*Hugin*) is also rated, relative to the other tools, more difficult to use. *BayesiaLab*, another highly ranked tool in terms of performance, is also ranked lower in "ease of use." *Netica* and *Analytica*, while easier to use, did rank lower in performance. The lack of a clear "winner" is further complicated by the fact that some extensions to the performance capabilities of both *Netica* and *BayesiaLab* are planned in the next release of these tools. None of these options is out of the running in terms of cost/price, and (of the five top-rated performance options) *SIAM* has the advantage of being available for licensing free of charge to government customers.

On balance, especially if ease of use is a critical factor for NASIC and the customer is willing to wait for the performance improvements (Table 12) planned

in the next release, *Netica* becomes a very attractive option. See Table 30 below for a summary of performance, usability and cost results.

Table 30. Project Results Summary

	Performance					Usability					Cost
	GF	IM	PE	IO	Overall Performance	US	EF	EM	VR	Overall Usability	Per 10 Licenses
Analytica	G	Y	B	B	G	G	G	G	G	G	**$51,000***
BayesBuilder	G	R	G	R	Y	NR	NR	NR	NR	NR	4000 Eu **($4,800)+ per seat**
BayesiaLab	Y	B	G	G	B	Y	Y	Y	Y	Y	17,250 Eu **($20,700)+**
Dxpress	G	Y	B	R	Y	NR	NR	NR	NR	NR	Provided at negotiation
Ergo	Y	R	B	Y	Y	NR	NR	NR	NR	NR	?
Hugin	G	B	G	G	B	Y	G	Y	Y	Y	12,550 Eu **($15,060)+**
Netica	G	Y	B	B	G	G	B	G	G	B	**$6,350****
SIAM	B	Y	Y	G	G	NR	NR	NR	NR	NR	Free
Bnet2000	R	Y	G	G	Y	NR	NR	NR	NR	NR	Not provided

Notes:
B = Best relative to others G = Acceptable Y = Marginal R = Worst relative to others
* ADE version, assumes (single seat price X10) minus 15% discount for 10+ licenses
** Price for site license (no price given for 10 seats)
+ Conversion to dollars assumes 1.2 dollars per Euro (approximate current exchange rate)

If NASIC/BPB wants further verification/validation of the results of this study before making an investment in a particular modeling capability, SRA recommends a more comprehensive evaluation using a sample or "benchmark" problem.

6.2 Study Limitations

There are some limitations on how these results should be used. An important factor when interpreting the results is to realize that the rankings for the tools were not generated based on building a Bayesian net using all the tools and then comparing the features. The ranks were primarily based on the responses from the tool vendors, information from the trial versions of the tools, and information on the web. In this process we might have overlooked some criteria that might prove useful when building a Bayesian model. Also, the final decision scores of the tools are a result of the criteria chosen and the weights assigned to them. The decision scores can change if a user evaluates the tools with a different set of criteria and different weights.

Another point to consider is that the SRA team worked with demonstration versions of these tools as they exist today. As planned extensions are added, and as more information is made available, these updates should be captured and considered in the analysis before finalizing an investment decision.

6.3 Recommended Follow-On Activity

SRA team members recommend further work to develop and implement a "benchmark" evaluation problem or scenario to verify the results of this study. As discussed above, tool rankings can be sensitive to both criteria and weighting. A sample problem or scenario that is representative of how the tools will actually be used by NASIC analysts can provide an additional level of insight and confidence to validate (or revise) these results.

6.4 Interest from Industry and Government

Many contacts (see Attachment 10) are interested in sharing the results of this effort.

7 Attachments

1. Requirements Trace, Influence Operations and PEBO Architectures
2. Analyst Questions
3. Project Criteria/Data Sheets
4. Definition of Terms and Tutorial Briefing
5. Prioritization Briefing
6. Market Survey Questionnaire
7. Questionnaire Response Raw Data
8. The Mitre Corporation Report
9. Significant Evaluation Issues and Ease of Use Analysis
10. POC List
11. Project Glossary

Attachment 1

Requirements Trace, Influence Operations and PEBO Architecture

REFERENCE DOCUMENTS	DESIRED EFFECTS	INFLUENCE OPS CAPABILITIES	INFLUENCE OPS MECHANISMS	PEBO FUNCTIONS	PEBO TASKS	PEBO SUBTASKS	PEBO SUB-SUBTASKS	ANALYST CAPABILITIES
JP3-13	Shae Decisions	Traditional PSYOP	Satellite photos	Perform PBA for Influence Operations	Manage ISR (TPED)			
JP3-53	Shae Behavior		Aerial recon photos		Establish IPB Baseline	Receive/process national objectives, ROE, CC intent, capabilities, institutional tendancies, phase information and develop IO objectives		Receive IO objectives
AFDD 1-1	Shae Perception		IO on comm network			Access and review relevant data (BPS, SPS, SPA, PSYOP studies, FPPPP, other sources)	Access and review relevant data (BPS, SPS, SPA, PSYOP studies, FPPPP, other sources)	Access and review relevant data (BPS, SPS, SPA, PSYOP studies, FPPPP, other sources)
AFDD 2-5	Demoralize		IO on computer network			Collect and analyze psychological and other human behavioral factors within the battlespace		
AF PEBO Architecture (Jul 03)	Preempt adversary action		Aircraft loudspeaker			Develop situational and culturally specific MOEs Perform detailed examination of human psychological vulnerabilities Determine psychological COGs and propose/predict COAs to achieve desired effect		Develop situational and culturally specific MOEs Perform detailed examination of human psychological vulnerabilities Determine psychological COGs and propose/predict COAs to achieve desired effect
FM 3-05.30	Dissuade		Aircraft broadcast					
FM 33-1-1	Couter adversary action		Air power presence		Develop Influence Ops Target Data (analyze specific human target vulnerabilities and enter info target folders)	Examine, predict behavior in response to COAs (scenarios, trade studies, what if exercises - consider target susceptibilities and accessibility)		Examine, predict behavior in response to COAs (scenarios, trade studies, what if exercises - consider target susceptibilities and accessibility)
OPNAVINST 3434-1	Communicate CC intent Provide accureate information		Air power noise Air power damage/destruction	Plan Deliberate PEBO	Analyze foreign influence indication (develop candidate indicators) Plan use within employment area Plan movement of capability into/within/out of employment area			
CUSTOMERS AF PEBO Planners in C/JAOC & in TBD PEBO Reachback IO Wing/Group/Squadron	Impct the decision cycle Prepare the battlespace		Air leaflet drop Air aid drop	Support Joint and Coalition PSYOP Planning	Establish liaison with Army			
	Encurage early end to conflict	Military Deception	Display of force Training exercise Other distraction activity Other confusion activity		Assist Joint planning operations	Determine objectives Analyze target Select themes and symbols Craft messages and other products		Analyze target
	Enhnce effectiveness of other air, spae or information operations	OPSEC	Essential elelments of friendly information Critical information list Security awareness training		Assist Joint product development	Test messages and other products to determine if desired effect is achievable		Test messages and other products to determine if desired effect is achievable
			COMSEC COMPUSEC Data permissions and marking	Command & Control of Influence Operations	Facilitate movement of products through available channels Develop Strategy, predict foreign COAs			
		Counter-Intelligence	Investigate/Identify/Assess threats Manipulate threat		Select target and specific means of influence	Plan PSYOP missions	Plan tactical PSYOP in direct support of air and space CC Plan air applications Plan space applications Plan networ applications Plan EW applications Plan agile combat support applications (e.g. force protection and deployment)	
			Deceive threat			Coordinate with military deception mission planning		
		Public Affairs	Repress threat Obtain awareness of info environment Collect timely/accurate info on target audience Media operations Internal information distribution			Coordinate with OPSEC mission planning Coordinate with media operations planning		
			Community relations Strategic communications planning Disrupt/damage/destroy adversary PSYOP resources and assets	Execute PEBO Missions (employ and disseminate products)	Dynamic operations control Assess operational influence Joint PSYOP product dissemination Tactical PSYOP employment Apply other domain influences (e.g. kinetic or non-kinetic capabilities that support PSYOP)			
		Counter-Propaganda						
		ISR - Support Kinetic Attack - Support Non-Kinetic Attack - Support		Support Influence Operations (Organize, train, equip, supply, protect forces)	Manage the IO enterprise	Strategic planning As-is and to-be architectures Modernization planning and guidance		Strategic planning As-is and to-be architectures Modernization planning and guidance
		AF Combat Camera - Support			Modernize	Manage owned operations and related resources MAA, MNA Select materiel and non-materiel solutions		MAA, MNA Select materiel and non-materiel solutions
						Conduct R&D, build prototypes, ATDs, ACTDs Produce and acquire platforms, weapons, systems, equipment, people		Conduct R&D, build prototypes, ATDs, ACTDs
					Train influence operators	Create, maintain a knowledge warehouse Provide input to TTP, IW doctrine Training and education	Support AF and Joint IO education Formal training courses, on-line applications Exercises	Create, maintain a knowledge warehouse Provide input to TTP, IW doctrine Support AF and Joint IO education Formal training courses, on-line applications Exercises
						Maintain ready personnel reserve		
					Provide forces (prepare, deploy, recover)	Generate, mobilize trained planners and operators Prepare forces for deployment Move forces to theater Return and reconstitute Assess readiness		
					Equip, supply, house, protect planners and operators (sustain forces)	Acquire, issue and maintain materiel and equipment	Acquire materiel and equipment Issue and control Maintain	
						Supply forces Coordinate facility space for units Protect forces	Coordinate security support Self-defense strategies	

REQUIREMENTS TRACE FROM CAPABILITIES TO CRITERIA

MODEL STRUCTURE (Source: NAIC/RPD)	ANALYST CAPABILITIES (Sources: See "T/I4CB From PEBO Architectures" Worksheet)	Further Definition of Analyst Capabilities (Source: NAIC Analyst Interviews)	EVALUATION CRITERIA:			
User Friendly Interface (I/O)	**Access relevant information**		**Text Mining Tool Criteria**	**Link Analysis Tool Criteria**	**Modeling Tool Criteria**	**Generic Criteria**
Text/Data Mining Tools	Receive IO objectives					
	Access and review relevant data (BPS, SPS, SPA, PSYOP studies, FPPPP, other sources)	Search thousands of documents for time, group, family, geographic relationships	Types of formats supported (MS Word, PDF, PS)	Types of data sources the tool can interface with (Structured data - ODBC RDBMS, others; Unstructured data - text, e-mail, web)		Maturity and risk issues
		Classified and open sources	Types of documents supported (e-mail, HTML, technical papers, etc.)	Amount of data handled		
		Data mining- populate a hierarchy of cultural/organization events	Types of features provided (e.g. clustering and categorizing multiple documents, document summarization)			
		Pattern search is important				
		Source bias assessment is important				
		Visual recognition is important				
		Help me find what I "don't know I don't know"		Ability to collaborate with other users		
		Sort, prioritize, organize > 1300 messages per day				
		Workload efficiency is key - help me with volume of information				
		Web based data access and sharing (nice to have)				
		Multi media (future)				
		Efficient loading and pulling			Input techniques used to weight the nodes and links; input techniques used for the CPT data (e.g. needs training, user can manually enter the CPT, not necessary (like SIAM)	
		Strong capability to organize data				
User Friendly Interface (I/O)	**Analyze target of interest**					
Relational Database	Develop situational and culturally specific MOEs	Flexible, adaptable to needs of individual analysts				Tool architecture (Client-server model, single client model, etc.)
Link Analysis Tools	Perform detailed examination of human psychological vulnerabilities	Weighting, link/node structure easily tailorable to TOI		Ability to add/delete nodes to the graph	Number of nodes a model can support	Maturity and risk issues
Modeling Tools (Bayesian basis)	Determine psychological COGs and propose/predict COAs to achieve desired effect	Evaluation tool separate from data mining/organizing tool			Number of event node restrictions on a cause node	
	Examine, predict behavior in response to COAs (scenarios, trade studies, what if exercises - consider target susceptibilities and accessibility)	At least 300 (scalable to ~ 3000) nodes			Implicit tree hierarchy of the model? If so, number of levels supported	
		Mature as information becomes available		Ability to add/delete nodes to the graph		
		SIAM-like logic/tracking train			Ability to encapsulate and group nodes into sub-components (to help organize the final model)	
		Effective display - "lay the evidence out logically, effectively, efficiently"	Ability to visualize semantic models of data	Link analysis (Type of query system support provided, how link analysis diagram is generated - semi-automated (tool aware of type of entities to look for) or only thru user-generated queries; network analysis; timeline/sequence analysis		
		Operator can assign probabilities and confidence levels	For multiple documents, types of views supported (list, cluster, timeline, co-occurrence, link/event view)		DAG or two-way model support	
		Spider diagram social network analysis capability	For a single document, types of views supported (document, summary, entity views)	Ability to "drill down" (capacity on the graph structure)	Graphical analysis techniques (sensitivity analysis, impact analysis)	
		Less training required, better			Ease of building the TOI model	Technical support requirements
		# Licenses likely less than 60				Cost and licensing issues
User Friendly Interface (I/O)	**Provide Required Products and Services**					
Modeling Tools (Bayesian basis)	Test messages and other products to determine if desired effect is achievable	Output formats meet needs of all customers		Ability to export graphs to other applications	Presentation of analysis results	
	Support to strategic planning	Interoperable with other agencies' tools (e.g. Visual Links, Analyst Notebook)		Ability to collaborate with other users	Model display capabilities (scaleable to fit screen, ability to scroll thru the model, printing capabilities, exporting the model to other documents)	Maturity and risk issues
	Help build as-is and to-be PEBO architectures	Internal data sharing within NAIC		Ability to collaborate with other users		
	Provide guidance to force modernization planning (input to TTP, IW, IO doctrine	Run on NAIC systems				System Requirements (Operating System, Memory, Hardware, etc.)
	Support MAA, MNA					
	Help select materiel and non-materiel targeting solutions for individual and small group TOIs					
	Support R&D, support building prototype capabilities					
	Support ATDs, ACTDs					
	Support exercises					
	Create, maintain a knowledge warehouse					
	Support AF and Joint IO education					
	Support formal training courses, on-line applications					

ATTRIBUTES

COG's	CULTURAL Nodes	ORGANIZATIONAL Nodes	PSYCHOLOGICAL Nodes	
Wealth	Values	Values	Perception	Attitudes
Land	Beliefs	Norms		Ambitions
Money	Language	Command Structure		Motives
Stocks	History/Experiences	Doctrine		World View
Products	Politics	Decision Making Process		Travel History
Possessions	Economics (including food/water)	Education/Training	Cognition	Preferences
Other exchange means	Preferences/Pressures/Expectations	Tools/Capabilities		Tendencies
	Religion	Type of Organization		Hierarchy of Needs
	Government	Organizational Politics		Desires
	Geography	Form of Government		Emotions
	Climate	Administrative Structure		Beliefs
Health	Ethnicity	Health Care		Dynamics of Group Behavior
Age	Myths	Concept of Justice		Group Identification
Physical fitness level	Social Structure	Security Force Influence		Self Identification
Psych fitness	Customs			Medical history
Emotional state	Kinship System			Leadership position
Injuries	Education System			Criminal record
Diseases	Conflict Resolution Mechanisms/Patterns			Employment history
Disorders				Values
Dysfunctions				Relationships
				Risk Tolerance
Image				Affiliations
Strength of purpose			Decision Making	Reasoning Patterns
Power				Decision loops
Charisma				Leadership style
Intelligence				Conceptualization
Integrity				Wealth importance
Loyalty				Health importance
Parsimony				Image importance
Aloofness				Relationships importance
Impatience				
Moral turpitude				
Selfish/selfless				
Relationships				
Immediate family				
Extended family				
Friends				
Associates				
Superiors				
Subordinates				
Peers				
Followers				
Enemies				
Disaffected followers				

Attachment 2

Analyst Questions

MEMORANDUM FOR RECORD

SUBJECT: 12 Sep 03 Analytical Capability for Behavioral Influence Operations Team Questions for Customer (Influence Operations Planners, Analysts)

TO: NAIC/BPB (Eric Braeden)

1. Eric, here is our first crack at a list of questions. Hopefully, this will continue our Task 1 progress toward a full understanding of how planners and analysts will use the tools. This will ensure we have the right criteria when we start evaluating candidates and alternatives in Tasks 2, 3, and 4.

2. Questions focused on the initial planning phase:
   2.1. Describe your planning cycle for a representative/relevant RFI or problem.
      2.1.1. Who is basic Customer set and what do they typically ask you to provide?
      2.1.2. What Official Documents, TTP, Regs and checklists do you refer to for guidance?
      2.1.3. Do you use any worksheets for PSYOP planning and research?
      2.1.4. What Information Sources do you use? Do you use and have access to the following Databases and programs?
         2.1.4.1.Special Operations Command, Research, Analysis and Threat Evaluation System (SOCRATES)
         2.1.4.2.Psychological Operations Automated Data System (POADS)
         2.1.4.3.Foreign Publication Procurement Program (FPPP)

3. Questions focused on the analysis process:
   3.1. Describe your PSYOP Target Audience analysis processes
      3.1.1. Type and Process
         3.1.1.1.Value analysis: Quantitative and Qualitative
         3.1.1.2.Nodal analysis
      3.1.2. What factors are taken into consideration?
      3.1.3. What are your target selection criteria?
      3.1.4. How do your targets get nominated and approved?
      3.1.5. How do you analyze secondary audiences for effects?
      3.1.6. What are a typical Timeframes for RFI's, process and production?
      3.1.7. Do you track/monitor PSYOP operations? How? (i.e., PSYOP Campaign Control schedules with PSYOP intensity, objectives, temporal schedules)
      3.1.8. Do you currently conduct a form of "PSYOP weaponeering for "targets"?
      3.1.9. Is environmental analysis taken into consideration and used? (Climate, Weather, and Geographic)
      3.1.10. How are "targets" tracked in databases? (~ BE numbers)
      3.1.11. What type of role do you play in execution planning if any at all?
      3.1.12. Do you conduct PSYOP Effectiveness Assessment?
         3.1.12.1. Are MOEs determined and measured? How?
         3.1.12.2. Are Objectives not met by MOEs incorporated into future planning, and PSYOP assessment?

4. Questions that dig into what cognitive, cultural, organizational characteristics are valuable to the analyst:
   - 4.1. Points on decision making style, group goals and organizational behavior were noted; however, is it useful to include other culturally-based influences in cultural models used to test software capabilities? Should primary focus emphasize any one of the following?
     - 4.1.1. Cognitive characteristics? (e.g., idiocentric vs. allocentric orientation, mastery vs. fatalistic orientation, past vs. present vs. future time orientation, etc.)
     - 4.1.2. Institutional characteristics? (e.g., Muslim, largely agricultural/pastoral, tribal affiliations, oil-based international economy with wealth clustered in ruling family, etc.)
     - 4.1.3. Sensitivities? (e.g., gender roles, caste/class systems, social position of children/elderly, social taboos, etc.)
     - 4.1.4. Other?
   - 4.2. How do you incorporate cultural knowledge into your planning now?
     - 4.2.1. Is culture a critical thread in all influence planning, a means of fine-tuning non-cultural influences, the focal point of some planning efforts, etc?
     - 4.2.2. Are cultural issues always specifically included in influence operations?
   - 4.3. How do you foresee incorporating culture in the future?
     - 4.3.1. Do you expect to increase employment of cultural influences?
     - 4.3.2. Do you need cultural matrices that map associated strains of cultural influences and relate specific cultural influences to specific groups?
     - 4.3.3. Are there plans to collect specific data on effectiveness of cultural influence employment?
     - 4.3.4. Are there plans to try to separate/evaluate the relative effects of specific circumstances on effectiveness?
   - 4.4. Can you give several examples in which culture played a role in NAIC product development?
     - 4.4.1. What are some representative cases?
     - 4.4.2. What are some atypical cases?

5. Questions focused on current tools that analysts use or are aware of:
   - 5.1. What type of Products do you currently produce?
     - 5.1.1. What are typical NAIC products like in format? (e.g., Army PSYOP forms, multi-page text reports?)
       - 5.1.1.1.How might cultural influences be incorporated in that format? (e.g., specifically identified, fully justified, or transparent to the user)
     - 5.1.2. What software do you use currently developing your products?
       - 5.1.2.1.What works for you?
       - 5.1.2.2.What doesn't work for you?
     - 5.1.3. What non-software supported techniques do you use currently to develop products?
       - 5.1.3.1.What capabilities would have helped you produce those products?
   - 5.2. What kinds of data base management systems are used now?

5.3. What is the nature of data that is useful to you now? (e.g., text, images, video, audio, etc.) Any expectations that this will change in the future?
5.4. Are data visualization tools used?
5.5. What types of decision modeling tools are used?
5.6. What type of tools would help you better perform PSYOP analysis?

6. We will be pursuing the answers to these questions through interviews with NAIC and other Influence Operations analysts over the next two weeks. Any assistance you can provide will be greatly appreciated.

Michael L. Zywien, Principal
Project Technical Lead

cc: Greg Jannarone
Capt Tim Gameros
Larry Daniel

Attachment 3

Project Criteria/Data Sheets

INPUT MANIPULATION	NETWORK TYPE			MODEL BUILDING			TYPE OF GRAPH SUPPORT			CONDITIONAL PROBABILITY TABLE				VALIDITY		INFERENCE ALGORITHM	ANALYSIS TECHNIQUES	LIMIT COMPUTATIONAL COMPLEXITY
TOOL	BAYESIAN	DECISION	BOTH	GUI	BATCH	STRUCTURE LEARNING	UNDIRECTED	DIRECTED	MIX	TABLES	EQUATIONS	LEARNING	OTHER	PROB CONSISTENCY	CYCLIC DEPENDENCY			
Analytica	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	Can provide general functional form of relations, including procedures to generate probability functions.	Yes	Yes	Monte Carlo and Hypercube	Importance Analysis; Parametric (Sensitivity Analysis); Alternative Analysis	No
BayesBuilder	Yes	No	No	Yes	Yes; via API	No	No	Yes	No	Yes	No	No	-	Yes	Yes	Junction Tree	Standard Conditioning of variables; computation of correlations and cross entropy between pairs of variables	No
BayesiaLab	Yes	Yes	Yes	Yes	-	Yes	No	No	Yes	Yes	Yes	Yes		Yes	Yes	Junction Tress & Likelihood weighting	Arc Analysis, Target Node Analysis, Target Modality Analysis,	?
Dxpress	Yes	No	No	Yes	-	No	No	Yes	No	Yes	No	No		Yes	Yes	Proprietary, to be discussed under conditions of confidentiality as needed.	?	Yes?
Ergo	Yes	No	No	Yes	Thru Script	Yes?	No	Yes	No	Yes	No	Yes?	-	Yes	Yes	Proprietary version of Lauritzen-Spiegelhalter JT; user can also enter likelihood ratios as evidence; inference can be performed in batch mode for validation, from GUI or API	Batch processing of inference for set of evidence cases.	No
Hugin Expert	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Supports missing information	Yes	Yes	Hugin Propagation - a.k.a junction tree	Conflict analysis	No
Netica	Yes	Yes	Yes	Yes	-	No	No	Yes	No	Yes	Yes	Yes		Yes	Yes	Elimination Junction Tree	Sensitive Analysis (~impact analysis that indicates how much the beliefs of query node will be influenced by a single finding at each of the other nodes.	No
OCCAM - Organizational and Cultural Criteria for Adversary Modeling (CRA Phase II SBIR)	Yes	No	No, but planned	Yes	No	No	No	Yes	No	Yes	No; not currently available within the CPT editor, but full cut and paste capability to/from Excel is supported	Yes; supports fully observable and partially observable data sets	Various other proprietary user interface techniques	Yes	Yes	Hugin Junction Tree Algorithm (not product, just algorithm)	Mutual information sensitivity analysis (similar to SIAM sensitivity analysis)	No
SIAM	Yes - Ilevence Netwos	Yes	Yes	Yes (influence diagram)	No	No	No	Yes (directed, acyclic)	No	See N	See N	See N	Sliding scale GUI (approximation to the full Bayesian matrix)	Yes - SW performs only probabilistically-based calculations. The belief of every node in an INET model is a number between 0.0 and 1.0.	Yes - INET models are ACYCLIC multiple-connected, directed graphs, so circular dependencies are not permitted in this application.	Does not support any inference. It uses CAST algorithm to calculate the belief of nodes (at the time of creation)	Impact analysis (which direct causes/parents hold the greatest influence over desired effects/children; Sensitivity analysis, (*pressure-parent, pressure points, highlighted pressure nodes*) - examine potential to change the likelihood of a desired event	N/A as it does not do any inferencing
Wargaming Asymmetric Environment (WAE)	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
SAMPLE	Yes - GRADE agentsconsist of networad components. Each component can excute a differat computational task, soh as Bayesin Netwox inferening or expert ystem rule praagation.	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	Yes	GRADE provides components that support fuzzy logic inferencing, Bayesian Network inferencing, and a simple expert system that provides forward chaining of rules.	Speculative analysis for Bayesian Networks is supported	No
PSYOP PT				Yes													MAUT as evidenced by SMART, and regression-based policy specifying (additional details in descriptive documents)	

PERFORMANCE EXTENSIBILITY	LANGUAGE USED		SRC AVAILABLE	API AVAILABLE	RUN TIME (Typical)	MAX NODES	ERROR RECOVERY SUPPORT
TOOL	*GII*	*Computational Engine*					
Analytica	C+	C++, Analytica scripting	No	Yes	No	Tens of thousands, each with multidimensional values; (Maximum nodes - 14830, sample size 32000 from specs doc)	Extensive diagnostic and error handling, including the ability to continue execution with partially undefined or infinite values. Interpretive mode makes it easy to find problems. Execution profiling (in Enterprise version) supports model optimization
BayesBuilder	Java	C++	No	Yes	No	No built in constraint- depends on complexity of the graph (clique size limited to 20) .	Java error messages
BayesiaLab	Java	Java	No	Yes	No	Limited by internal memory. Worked on a genetic data base containing 2000 columns with 3 modalities for each gene on a 1ghz PC with 256 MO without problem.	Exceptions throwned by the Java Virtual Machine are catched and it is possible to automatically send the error message to Bayesia so that we can correct the error. If the exception is relative to memory, a specific window explain what parameters have to be change to allow BayesiaLab to work with more memory.
Dxpress	C+	C++	No	Yes	Yes - Load testing?	Performance limit has not been established, however, 400-node, multi-fault networks have been built and operated. In general, the limitation on node number is the ability of the developer(s) to understand the resulting network at a deep level. We have found that for a team of experienced elicitors, an effective limit of 400 nodes per network applies. We solve the large network problem by a domain division method. For example, in one major application of over 700 networks, the applicable network is selected by a meta-network.	?
Ergo	C+	C++; API supports C or C++	No	Yes	-	Limited by available memory; maximum number of conditional probabilities per node is 2^32	Yes, GUI and API return error codes for all errors/warnings
Hugin Expert	Java	C	No	Yes	Yes, slides attached	Limited by available memory	Yes, All functions set error code
Netica	C+	C++	Under special circumstances	Yes	No	Limited by available memory	Yes, API has a very robust support (crash proof)
OCCAM - Organizational and Cultural Criteria for Adversary Modeling (CRA Phase II SBIR)	Java	Java (for both rules and BNs)	Not generally available to government end user; would need to be negotiated	Yes	No benchmark procedure or performance measurement information provided	Only limited by CPU and memory; on recommended system, supports on the order of 1000 nodes depending on network density	Use last saved state (no intermediate or auto-save features currently implemented)
SIAM	Java	Java	No	No	Did a lot of benchmarking until ~ 1998 - even largest problems can be run in under 1 minute, so stopped doing a lot of performance measurement	No SW limitations, but modeling approach may restrict number of variables to a maximum that can be fully understood by the human user.	Backup file is created at the time a net is opened - manual saves after that; can trap internal crashes, but not network crashes
Wargaming Asymmetric Environment							
SAMPLE	Java	Java, but components can use JNI to access other languages and system libraries	No, but may be negotiated	Yes, the GRADE component API is available to support the construction of new third party components	No - performance measurements are currently under development	No maximum	GRADE supports creation of a central log file, and error handlers to respond to errors
PSYOP PT	Active server pages, VBScript	Active server pages, VBScript	Yes	No	No benchmark procedure or performance measurement information provided	No hard limits - only limited by physical memory	Software automatically saves inputs as the user works. If a system failure occurs, the user can pick up exactly where they left off.

INTEROPERABILITY	DATABASES					EXPORT FILE SUPPORT		USE OPEN STANDARDS	GROUP COLLABORATION
	INPUT ACCESS		*SQL INTERFACE*	*SAVE MODELS*	*MODEL FORMAT*	*EXPORT MODEL*	*RESULTS FROM ANALYSIS*		
TOOL	*DIRECTLY*	*USING ODBC*							
Analytica	No	Yes	Yes	Yes	XML	Yes. To editors that support XML format and word processor	Can copy and paste, or OLE hotlink tables and graphs to Microsoft Excel, PPT, many other common windows applications. Can use Excel seamlessly for graphing results. Can save table results into tab-limited files for viewing and anlaysis in Excel or most statistical and database packages	Yes. OLE, XML, ODBC support	Yes. Multiple users can collaborate in building models, and can distinguish inputs and scenarios by multiple users or experts by indexing
BayesBuilder	No	No	No	No	Text file (ASCII), possibly encrypted. Other save formats are not supported	No	Yes, Images can be exported to gif, jpeg	Yes, Inference is standard junction tree (with the complete-neighbour heuristic for constructing the junction tree	No
BayesiaLab	?	?	No	No	XBL, a specific format based on XML. BayesiaLab can also read BIF and NET networks.	No	Yes. It is possible to paste the monitors to any applications that interact with the clipboard of the OS. Monitors can be pasted as texts, arrays or images.	Yes, Bayesian Interchange Format (BIF)	Yes
Dxpress	?	?	No	No	Proprietary	No	Yes??	No	No
Ergo	No	No	No	No	Proprietary binary (more efficient); text; XML	Yes?	GUI saves graph to clipboard for export to drawing programs	No	No
Hugin Expert	Yes (Oracle 8i)	Yes	No	No	NET, HKB	Yes, B-course, Genie, Samiam	Yes, Images exported to BMP format	Yes (all major algorithms)	No
Netica	-	Yes. Had issues with Linux. Suggestion is to learn to use this feature under windows and then move to Linux	No	No	.dne, .net	No. But can read Hugin, Ergo, Dxpress Models	Yes. Using API, can write the results to Excel, Word, etc. With GUI, can copy and paste the results to PPT, Excel, Word	Yes. Uses know inference algorithm	No
OCCAM - Organizational and Cultural Criteria for Adversary Modeling (CRA Phase II SBIR)	Yes; application supports SQL queries to retrieve data used as evidence in the networks; also, the rule engine component can store rules in a database; Bayesian network component receives data from the database via the domain model of the main application	Yes; the JDBC 2.0 bridge used supports the ODBC 2.x and ODBC 3.x driver manager and drivers, so any database that supports those standards	Yes	Yes; not Bayesian networks, the application level data is saved in a database and any ruleset may also be stored in a database; xbn (standard xmlBN format) is used to save BNs; proprietary ruleset format is used to save rules		Yes; model can be exported to any application that will read the common xbn format; rulesets are not currently exportable	Yes (this feature is currently under development); BNs model can be exported to any application that reads xbn files; rules model cannot currently be exported; domain model is stored in a database that is accessible via SQL queries; also, results of analysis can be captured in standard image formats (e.g. jpeg, gif)	Yes; in the BN model, save model to xbn files (xml bnet standard); cut/paste CPT entries to/from Excel; SQL syntax for querying data in domain model	No
SIAM	No - stored in .inet flat file	N/A	N/A	No (model cannot be saved to a database)	Based on XML, (it's a serialized object)	Yes - Influence nets can be saved as Postscript files and then imported and inserted into another application that supports this type of file; Also supports XML (web page display, transform to spreadsheet or database applications) and BIF (Bayesian Interchange Format)	Yes - Model reports may be saved as .pdf, .rtf, or .html files; can cut and paste from screen to other files; output can be printed to text based reports (e.g. Word, Powerpoint); users can also create their own templates for reports and than save	Yes; client-server version for US Government customers allows 1 PC to serve as host, 2nd PC server that connects individual users; high level file can take input from lower level files	Yes
Wargaming Asymmetric Environment (WAE)									
SAMPLE	No	N/A	No information	.XML format used to save models	No	No	Yes, Java component extensibility, RMI XML messages, and XSL transformations	Yes - Bayesian networks, fuzzy systems and rule bases can be exported and imported between constructed agents.	
PSYOP PT	Yes	Yes - Microsoft Access	Yes	Yes	No	No		Yes	

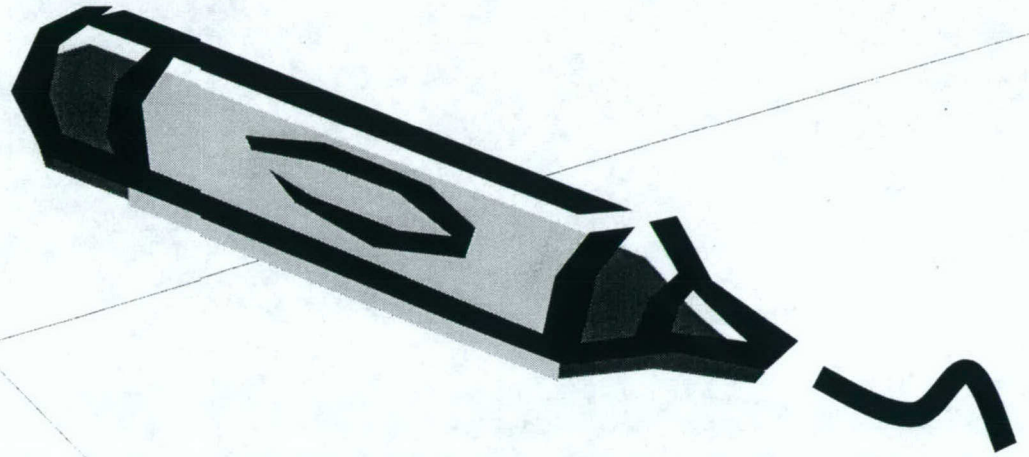
CONTACTS

TOOL	INITIAL CONTACT DATE	POC	E-MAIL ADDRESS	PHONE	STATUS (Received Yes or No)
Analytica	10/20/2003	Maylene McMillan; Max Henrion	henrion@lumina.com		Yes
BayesBuilder	10/22/2003	Wim Wiegerinck	wimw@snn.kun.nl		Yes
BayesiaLab	10/15/2003	Lionel Jouffe	jouffe@bayesia.com		Yes
DATA 4.0	10/22/2003	Andy Sheldon	andy@treeage.com		N/A
Decision Programming Language (DPL)	10/21/2003	Tony Manzella	tmanzella@syncopationsoftware.com		N/A
Dxpress	10/21/2003	Edward Olmstead	olmstead@kic.com		Yes
Ergo	10/21/2003	Edward Herskovits	ehh@noeticsystems.com		Yes
Hugin Expert	10/20/2003	Anne-Mette Christensen	Anne-mette.Christensen@hugin.com		Yes
iDecide	10/15/2003	Andy Killinger	akillinger@decisivetools.com		N/A
Netica	10/20/2003	Brent Boerlage	boerlage@norsys.com	604-221-2223	Yes
JEMNA	10/30/2003	Phil Desmaris		540-653-5757	Yes
OCCAM - Organizational and Cultural Criteria for Adversary Modeling (CRA Phase II SBIR)	10/20/2003	Dr. Jonathan Pfautz	jpfautz@cra.com	617-491-3474 x541	Yes
PRFECT	10/20/2003	Randy Clark		505-853-2295	N/A
SIAM	11/10/2003	Dr. Julie Rosen	JULIE.A.ROSEN@saic.com	703-676-7354	Yes
Wargaming Asymmetric Environment (WAE)	10/22/2003	Larry Willis	lwillis@darpa.mil	703-696-7448	No - will provide detailed information directly to government customer (provided short description)
SAMPLE	10/30/2003	Karen Harper	kharper@cra.com	617-491-3474 x533	Yes
PSYOP PT	10/29/2003	Brice Stone	bricestone@stic.net	210-545-1028	Yes

Category	tel Wt	Subcategory	Rel Wt	Sub-sub Category	Rel Wt	Sub-sub-sub Category	Rel Wt
		Case 1:					
Input Manipulation	**1**	**Both B, D**	N/A	Probability	1	Equations	1
						Learning	2
						Other	3
				Analysis Technique	1		
				Inference Algorithm	2	Exact and Approx	1
						Exact or Approx (Exact favored)	2
						Neither	3
				Virtual Evidence	2		
				Mix Graph Support	3	Yes	1
						No	2
				Structure Learning	3		
		Case 2:					
		Either B or D	N/A	Probability	1	Equations	1
						Learning	2
						Other	3
				Analysis Technique	1		
				Inference Algorithm	2	Exact and Approx	1
						Exact or Approx (Exact favored)	2
						Neither	3
				Virtual Evidence	2		
				Mix Graph Support	3	Yes	1
						No	2
				Structure Learning	3		
Performance Extensibility	**2**	Computational Engine	1	C/C++	1		
				Java	2		
		GUI	2	C/C++	1		
				Java	2		
		Benchmark	3	Have	1		
				Don't Have	2		
Interoperability	**2**	Open Stds	2	XBN, XML	1		
				XBN and/or XML, but their format is more efficient	2		
				Proprietary	3		
		Export Analysis Report	1	Select on screen	1		
				Save, then export	2		
				Format restrictions	3		
		Export/Import Model	3				
		Database Input Access	2	Use ODBC	1		
				Direct	3		
				Save Models	2		
				SQL Interface	3		
General Features	**3**	Architecture	1	Both CS & DT	1		
				Only DT	2		
		Maturity	2	>5 years	1		
				<5 years	2	>2 years	1
						<2 years	2
		Operating Sys	3	W, L, M	1		
				Other	2		

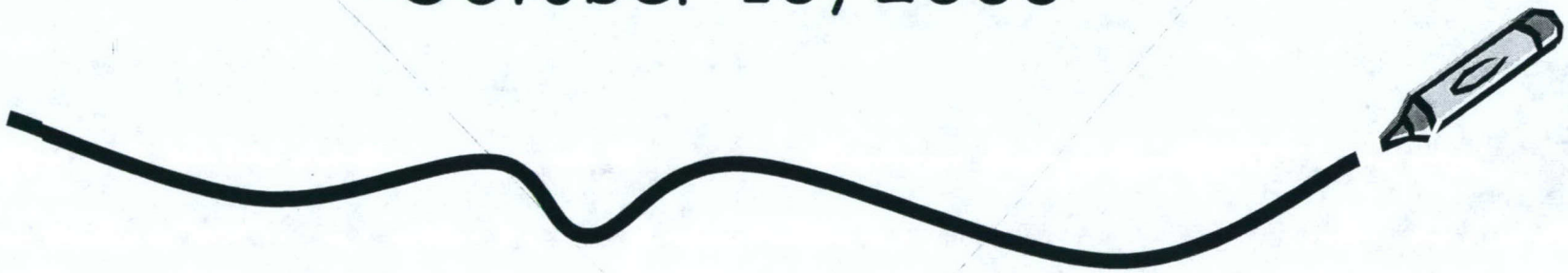
Attachment 4

Definition of Terms and Tutorial Briefing



Definitions/Tutorial

October 10, 2003



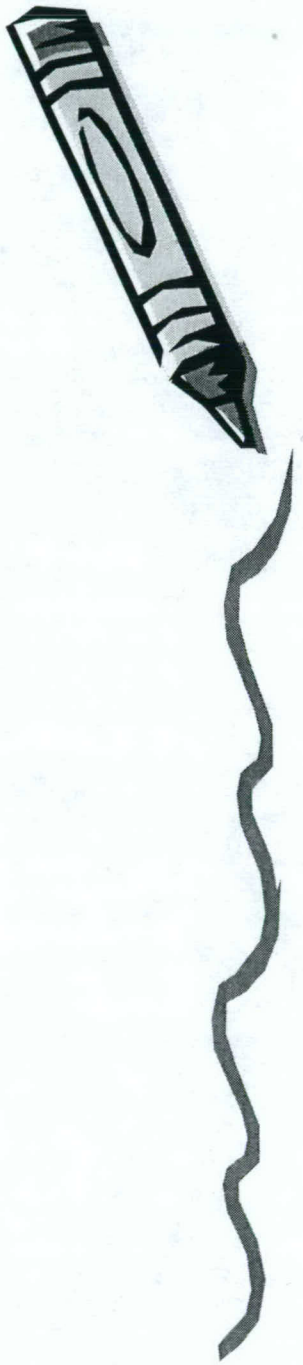
Terms that keep coming up

- Probability Theory
- Decision/Utility Theory
- Bayesian/Belief/Causal/Probability Nets
- Influence Diagrams
- Decision Trees
- Criteria model

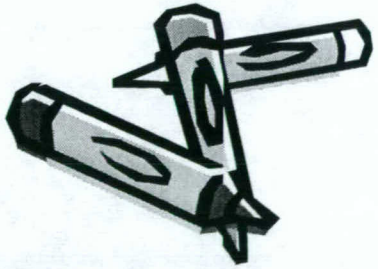
Terms in Detail..

- Probability Theory - Notion of Prior and Posterior Probabilities
- Decision/Utility Theory - Concept of maximization of Utility function
  - Given a set of criteria and a set of alternatives, find an alternative that maximizes utility function

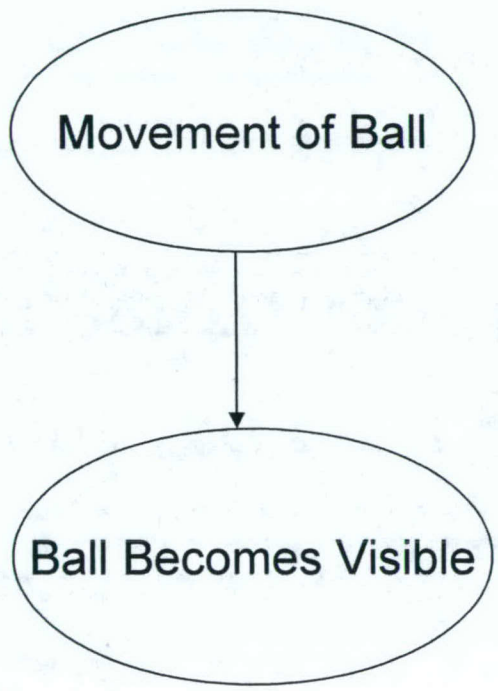
Bayesian Network (BN)



- Concept based on Probability Theory
- BN is used to represent dependencies between random variables
- Dependency between nodes is denoted by a directed link
- Every node is associated with Conditional Probability Table (CPT)
  - CPT represents information about the effect of parent nodes on the child node.



A simple BN



P(movement =toward)
0.7

Movement	P(visible)
Toward	0.4
Away	0.05

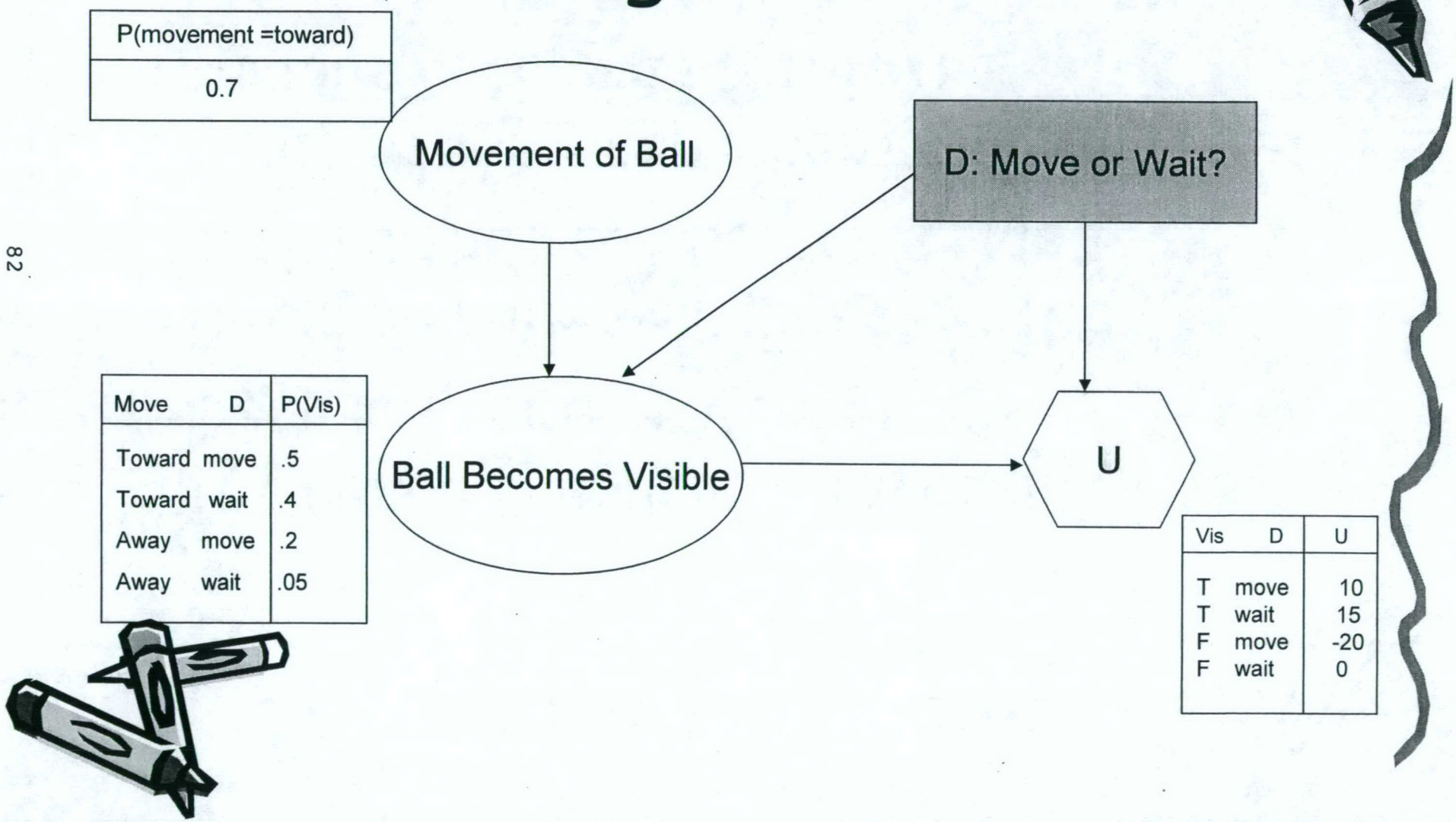
Populating CPT's

- Manual entry by the user
- Learning from training data
- Partial representation (like SIAM)
- Other?

Influence Diagrams

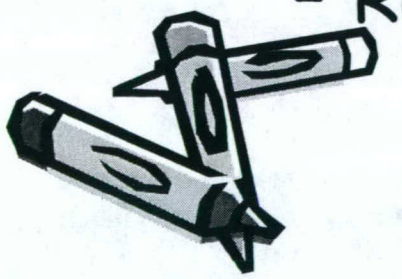
- Influence Diagram = Bayesian Nets + Decision nodes + Value nodes
- Decision nodes – represent the actions that can be performed
- Value nodes – represent the values of various outcomes (utility)

Example of Influence Diagram

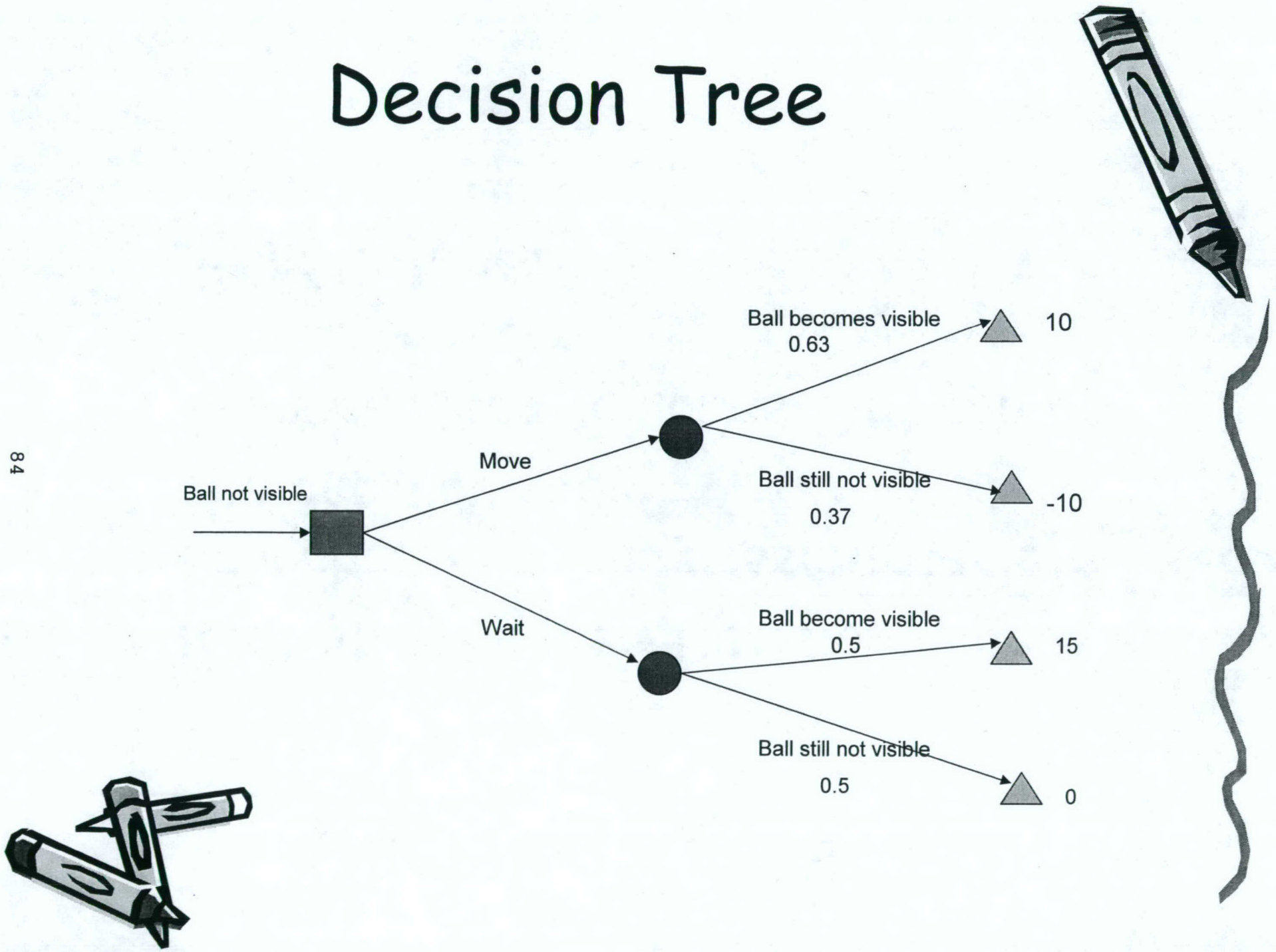


Decision Trees

- Problem is chronologically modeled
- Root of the tree - Decision node
- Branches – various possibilities of the decision node.
- Branches lead to nodes that can be
  - Decision nodes
  - Chance nodes
  - Result nodes



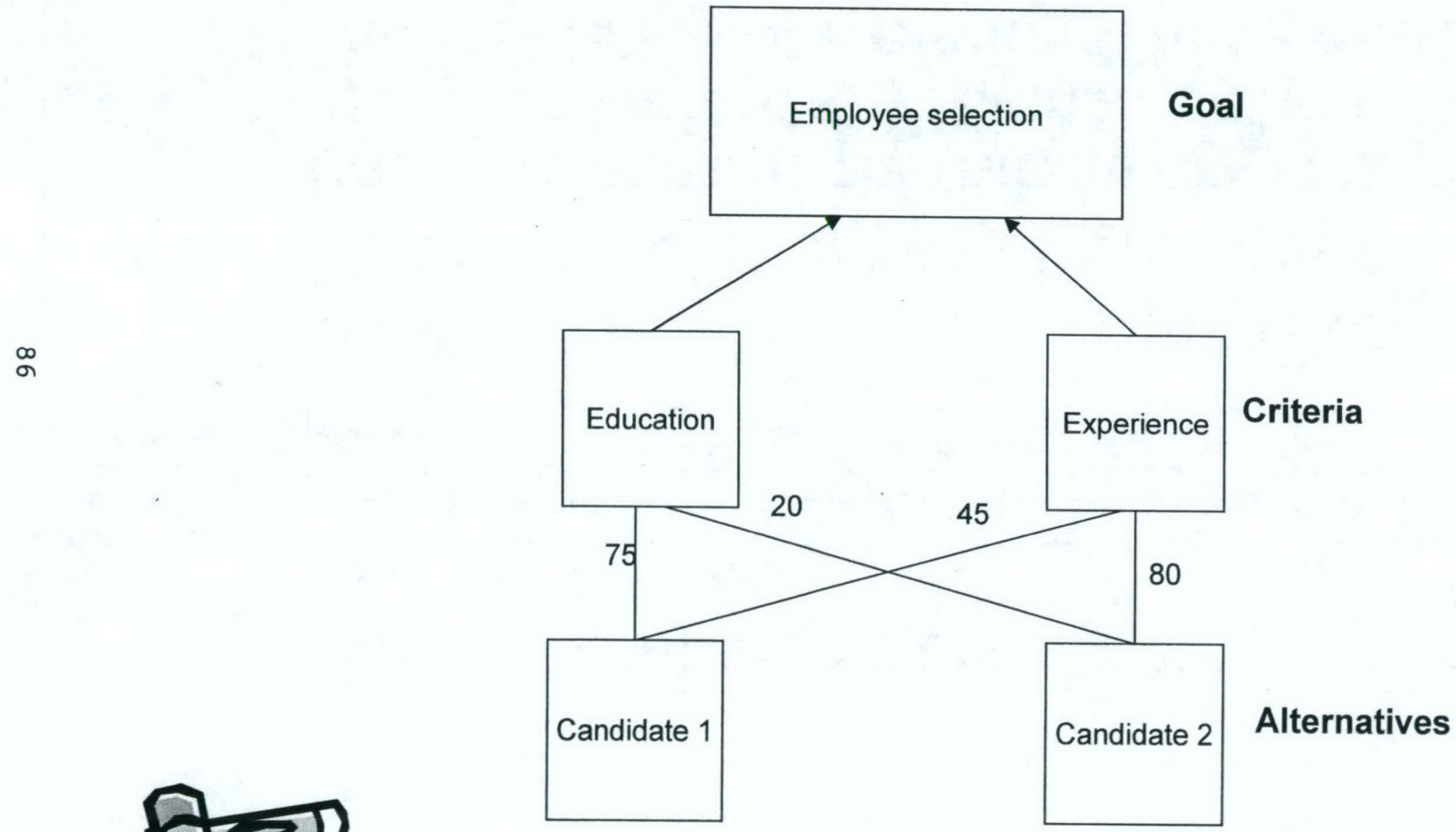
Decision Tree



Criteria model

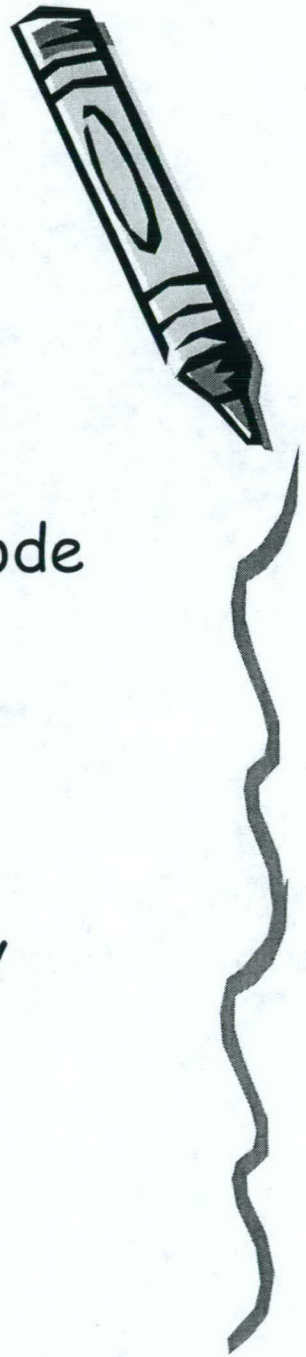
- Hierarchical structure
- Top level – Goal
- Next level – criteria directly effecting goal
- Subsequent levels – subsequent criteria
- Bottom level – all the alternatives
- Each element in the hierarchy must be assigned weights. Weights determine the influence one element has on other elements

Criteria Model Example



Evaluating Networks

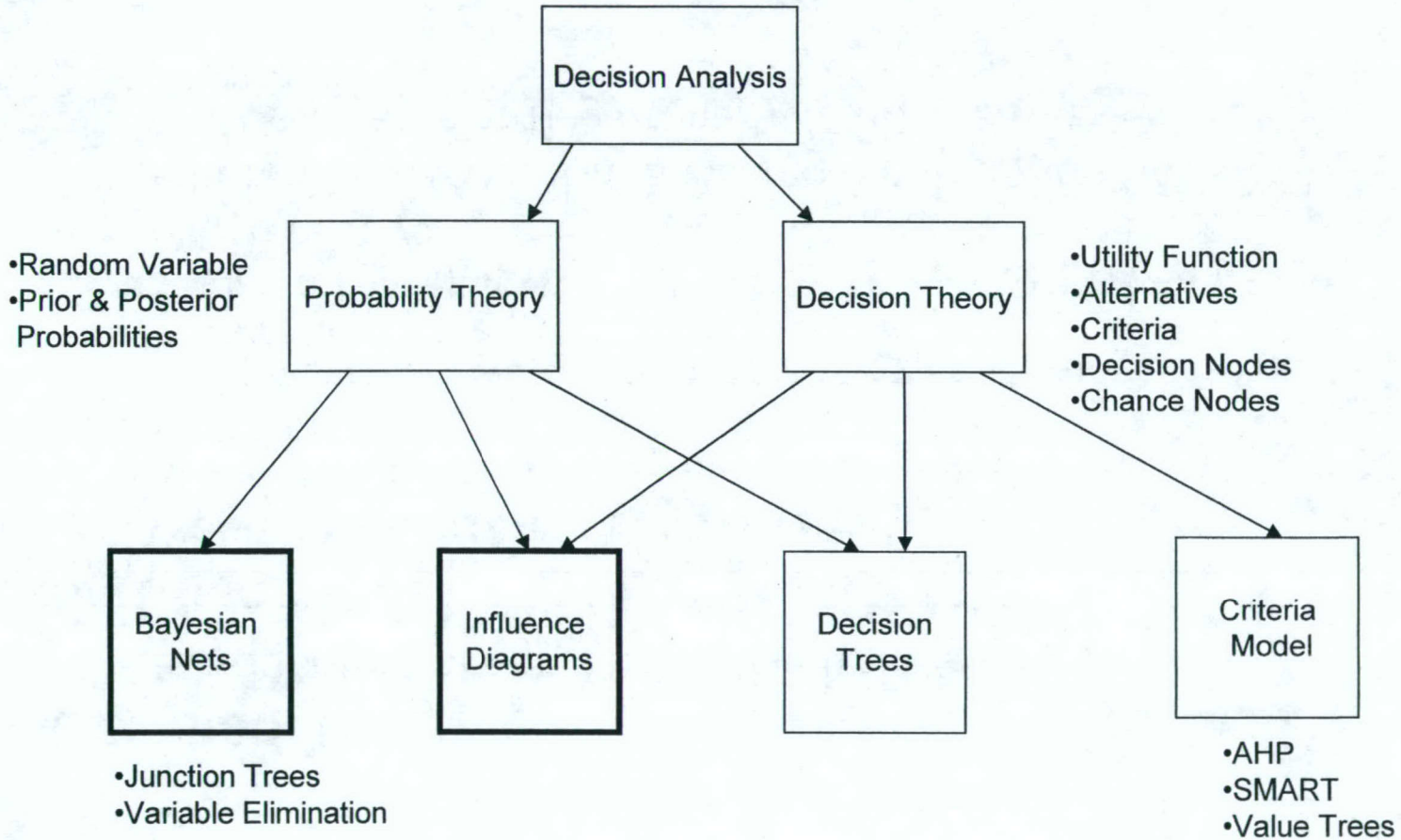
- Bayesian Nets – Based on Bayes' theorem. Calculating the posterior probability distribution for some random variables given the exact value for other variables
  - Clustering
  - Conditioning
  - Elimination
  - Stochastic Sampling



- Influence Diagrams -
  - For each possible value of the decision node
    - Set the decision node to that value
    - Calculate posterior probabilities (using BN techniques)
    - Calculating resulting utility value
  - Return the action with the highest utility

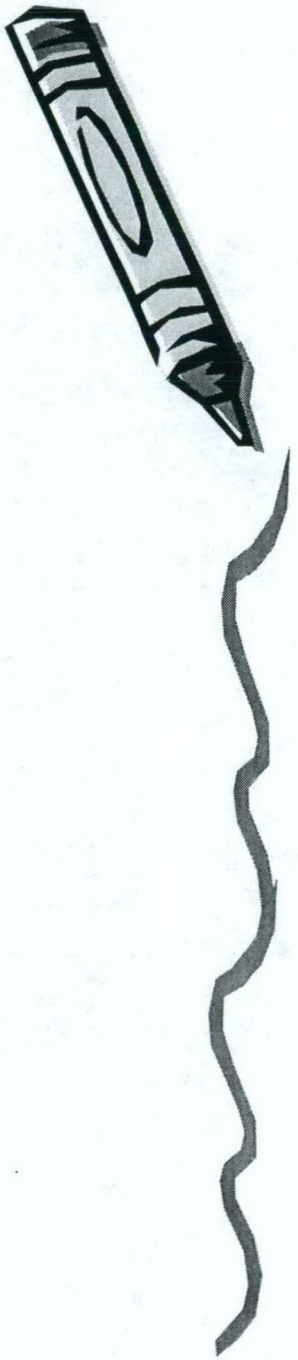
- Decision Trees
  - Use dynamic programming techniques
- Criteria Model
  - Analytic Hierarchy Process (AHP)
    - Relative weighting of multiple alternatives against given criteria.
    - The criteria weighted in terms of importance to the decision maker.
    - Value function that calculates the overall score of an alternative
  - Simple Multi-Attribute Rating Technique (SMART)
    - Absolute weighting of multiple alternatives against given criteria.

Summary


Decision Analysis
Probability Theory
Decision Theory
•Random Variable
•Prior & Posterior Probabilities
•Utility Function
•Alternatives
•Criteria
•Decision Nodes
•Chance Nodes
Bayesian Nets
Influence Diagrams
Decision Trees
Criteria Model
•Junction Trees
•Variable Elimination
•AHP
•SMART
•Value Trees

Summary Contd..

- Steps involved in Modeling
  - Build the model
  - Assign values, weights, beliefs, etc
  - Use inference to answer queries
- Performance



Questions?

- \\Dayton2\Projects\NAIC Infulence Ops\Working\Questionnaire and Data\Questionnaire.doc

Greg's Macro Criteria

- 1. Bayesian-based/inferential design, to permit probabilistic, or levels of confidence, outputs
- 2. Analyst-friendly and (relatively) quickly trainable operation
- 3. Links and nodes derivation and representation, especially for "weighting" of the (influence) links and (individual/group) nodes
- 4. Relational data/knowledge base utilization and applications functionality
- 5. Representation (based eventually upon our team's on-going characterization) and weighting of qualitative or degree-of-applicability KEY influence factors [Don't be concerned for the specific factors or their characterization; they will be based upon crisp, plain language expression and similar to "expert" identification and consensus approaches]

Attachment 5

Prioritization Briefing

PROJECT STATUS UPDATE

5 NOV 03

Ratna Bearavolu
Software Engineer
Adroit C4ISR Center
SRA International, Inc.

Today's Purpose

- Review project scope
  - Funding reduction impact
- Present project execution to date
- Discussion - Feedback

Heading Check to Ensure SRA Provides Maximum Value to our Customer

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Overview

- Review Project Scope
  - Funding/Schedule
  - Requirements
  - Project Focus
- Execution status
  - Criteria
  - Contacts
  - Market Survey
  - Prioritization
  - Status (data, report)
- Discussion - Feedback

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Scope

- Project plan presented on 2 Sep has changed
  - Funding reduced
  - NAIC/SRA agreement on re-scope documented in 30 Sep Memo
    - Task 1 (Criteria) – No impact
      - Requirements trace - architecture to criteria - complete
    - Task 2 (Market Survey) – 90% modeling
    - Tasks 3 and 4 (Analysis) combined
    - Task 5 (Demonstrations) eliminated
    - Task 6 (Final report) – Draft outline available

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Methodology

- Ensure requirements are well understood
- Map requirements to criteria (modeling)
- Establish list of candidate tools
- Develop questionnaire tied to criteria
- Phone or personal contact, followed up with questionnaire
- Enter data from completed questionnaires (follow up as necessary) Where we are today
- Analyze data
- Report results to customer

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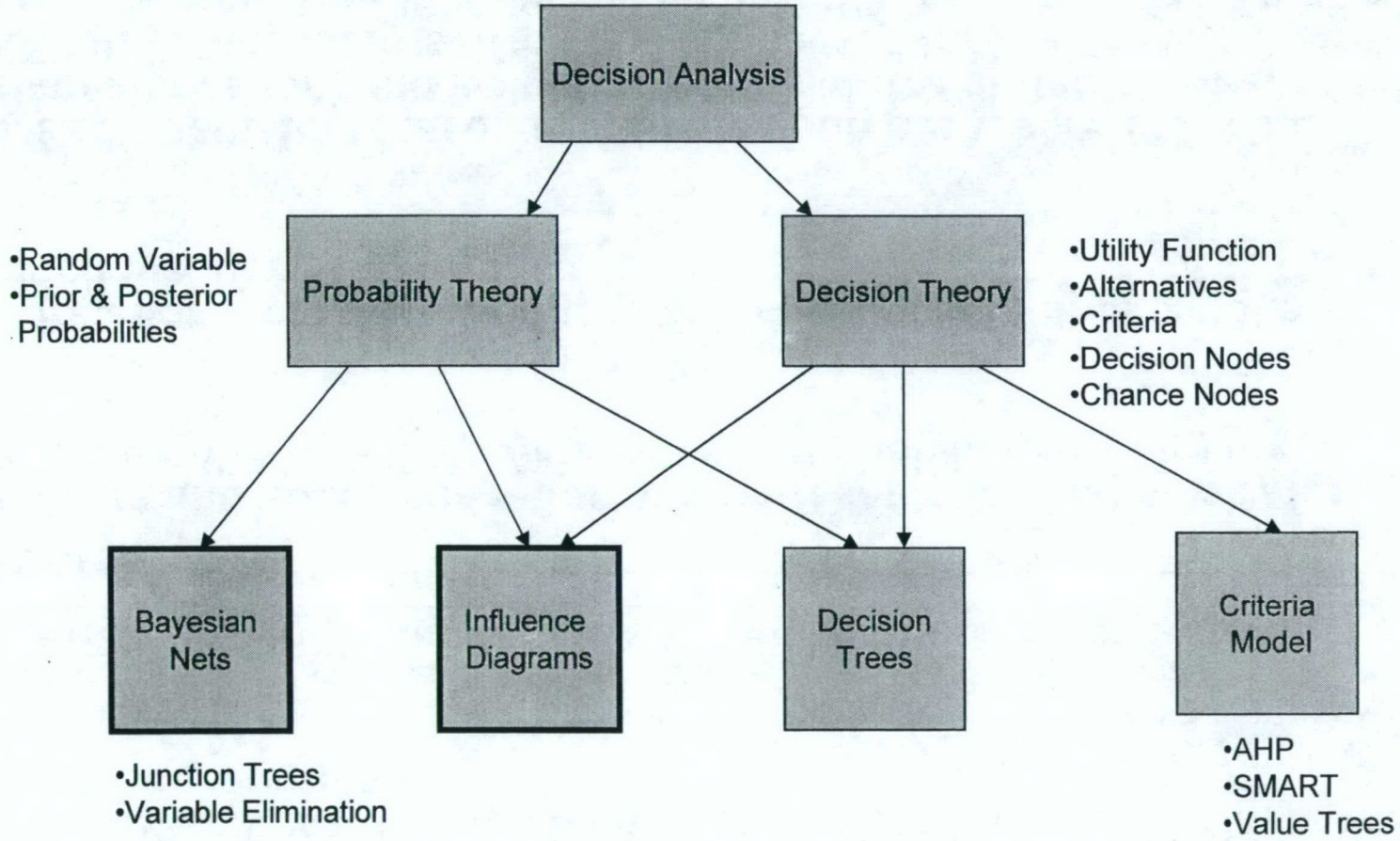
Macro Criteria

- 1. Bayesian-based/inferential design, to permit probabilistic, or levels of confidence, outputs
- 2. Analyst-friendly and (relatively) quickly trainable operation
- 3. Links and nodes derivation and representation, especially for "weighting" of the (influence) links and (individual/group) nodes
- 4. Relational data/knowledge base utilization and applications functionality
- 5. Representation (based eventually upon our team's on-going characterization) and weighting of qualitative or degree-of-applicability KEY influence factors [Don't be concerned for the specific factors or their characterization; they will be based upon crisp, plain language expression and similar to "expert" identification and consensus approaches]

Elements of Decision Analysis



Detailed Criteria

- Criteria developed from understanding requirements:
  - Customer vision, direction (macro criteria)
  - PEBO Architecture analysis
  - Interviews with analysts, company SMEs
  - Requirement Trace Matrix
- Using 4 criteria "categories:"
  - General Features
  - Input Manipulation
  - Performance Extensibility
  - Interoperability
  - Questionnaire
- Questionnaire mapped to Excel Data Capture Sheet
  - Questionnaire mapped to spreadsheet

Contacts

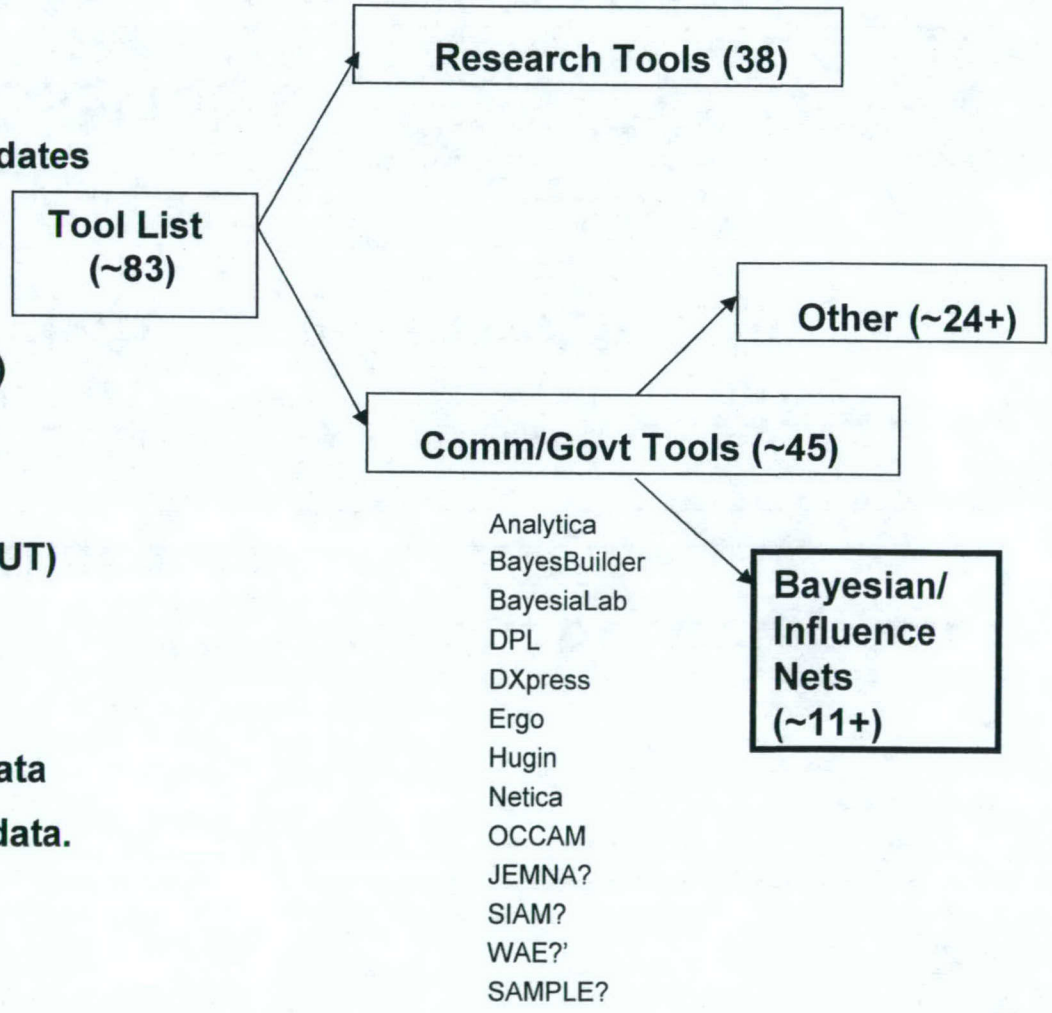
- NASIC
- AFRL/HE
- ASC/ENM
- JIOC
- DARPA
- SIMAF
- 4TH POG
- AIA/DO-2
- JWAC
- NSA
- CIA
- DIA
- AAC (Eglin)
- Charles River Analytics
- SRA International
- Klein Associates
- Mission Research Corp.
- Universities

Market Survey

- Text Mining
  - Looked at NetOwl Extractor early on, but not much time spent beyond that yet
- Social Network Analysis
  - Analyst Notebook, Visual Links, InstaLink, Starlight
- Modeling
  - 35 relevant commercial tools
  - Approx. 10 relevant govt-sponsored tools
  - 38 relevant research efforts

Priority

- **IMPORTANT: Tools that support**
  - Bayesian and Influence nets
  - Manual construction of nets
  - Support evidence entry and belief updates (diagnostic inference)
- **NOT IMPORTANT:**
  - Tools that are add-ins to other applications (ex: spread sheet add in)
  - Tools that rely on
    - Decision tree technique
    - Multi Attribute Utility Theory (MAUT)
    - Our domain is too big to be represented as one of the above
  - Tools that provide data mining capabilities given large amounts of data
    - We don't have large amounts of data.



Status

- Some capabilities on original list are not worth further effort
- Initial contact made with all priority candidates
  - Getting cooperation from contacts
  - Several questionnaires returned
  - Follow up in progress for both returned and non-returned questionnaires
  - Data from the questionnaires
- Analysis in preliminary stages, but a few capabilities are starting to emerge as good candidates for the NAIC modeling mission
  - Netica
  - Analytica
  - Hugin Expert
- Many contacts are interested in sharing results of this effort

Discussion: Feedback?

(Would like to schedule next heading check in early December)

Attachment 6

Market Survey Questionnaire

Tool Name:
Website:
Company Name:

General Features

1. Ease of use: **(B)**

- Is there feedback for processing delays?
- Do menu items and text descriptions use language that is commonly understood?
- Are menu items in standard places? Are layouts, terms, icon screen positions, windows, dialog boxes consistent?
- How many steps does it take to perform a frequently used action (desire not buried in menus; not multi-step)?
- Do you show user that he/she has made a mistake? How is user aided in correcting mistakes?
- Do you visually display system objects, actions, and options to users or are these available textually? How do you aid users' memory for these choices? Are instructions easily available if the user forgets or loses his/her way?
- Does your system cater to novice and expert users? Allow users' to create shortcuts for frequently used actions?
- How is help and/or documentation provided to the user?
- How does your software handle making best use of limited screen "real estate"?
- Top 5 "trouble" reports?

2. Cost: Seat license; upgrades; support; maintenance; (for government customer)**(C)**

3. Maturity of the tool: Number of years in the market, # versions/upgrades. **(D)**

4. Targeted Industries: Business, medical, govt., etc **(E)**

5. Major clients: **(E)**

6. Type of Operating system supported: List all applicable OS **(F)**

7. Recommended Hardware: (list both minimal and optimal) **(G)**
   a. Processing power:
   b. RAM:
   c. Other:

8. Architecture support: **(H)**
   a. Client – Server Model: Yes ☐ No ☐
   b. Desktop: Yes ☐ No ☐

Input Manipulation

1. Type of Network support:
    a. Bayesian Networks: Yes ☐ No ☐ **(B)**
    b. Decision Networks/Influence Diagrams: Yes ☐ No ☐ **(C)**
    c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☐ **(D)**
    d. Decision Trees: Yes ☐ No ☐ **(C)**

2. Model Building capability:
    a. Using GUI: Yes ☐ No ☐ **(E)**
    b. Other: Using a custom language, batch mode etc **(F)**
    c. From databases (i.e. Structure learning): Yes ☐ No ☐ **(G)**

3. Type of graph support:
    a. Only Undirected graph: Yes ☐ No ☐ **(H)**
    b. Only Directed graph: Yes ☐ No ☐ **(I)**
    c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐ **(J)**

4. Conditional Probability Table:
    a. Specify Tables: Yes ☐ No ☐ **(K)**
    b. Specify Equations: Yes ☐ No ☐ **(L)**
    c. From databases (learn from training sets): Yes ☐ No ☐ **(M)**
    d. Other: Other Input techniques used **(N)**

5. Validity of the model:
    a. Consistent Probability check of variables in the net: Yes ☐ No ☐ **(O)**
    b. Cyclic Dependency structure check among variables: Yes ☐ No ☐ **(P)**

6. Inference Algorithm used: List all relevant algorithms **(Q)**

7. Analysis techniques provided/supported: List and explain **(R)**

8. For tools using Bayesian Networks (Ref. Col B data) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☐ **(S)**
    a. If yes, explain: **(S)**

Performance and Extensibility

1. Language used to develop:
    a. GUI: **(B)**

    b. Computational Engine: **(C)**

2. Is source code generally available to a government end user: Yes ☐ No ☐ **(D)**
(If no, is there any circumstance where the source code could be made available?)

3. Is the API available to the end user: Yes ☐ No ☐ **(E)**

4. Availability of the tool's performance measurement: Yes ☐ No ☐ **(F)**
    a. If yes, please indicate the benchmark/procedure used to measure performance:

5. Maximum Nodes a single model can support: Max nodes a model can support when running on the recommended system **(G)**

6. Error recovery support (if something crashes, what happens?): **(H)**

Interoperability

1. Ability to interface with databases: Yes ☐ **(B,C)** No ☐
    a. If Yes,
        i. Using Open Data Base Connectivity (ODBC): Yes ☐ No ☐ **(C)**
            1. If Yes, list the data bases the ODBC driver supports:

        ii. Databases it can interface directly with (List them): **(B)**

    b. Does it support SQL interface: Yes ☐ No ☐ **(D)**
    c. Can models created in the tool be saved to a database: Yes ☐ No ☐ **(E)**

2. Format used to the save the model: **(E)**

3. Export the model to other applications: Yes ☐ No ☐ **(F)**
    a. If yes, list the applications the model can be exported to: **(F)**

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☐ No ☐ **(G)**
    a. If Yes, list applications that it can be exported to: Eg: PPT, Word, JPEG, PDF format, PS format, etc **(G)**

5. Tools uses open standards: Yes ☐ No ☐ **(H)**
    a. If yes, explain: **(H)**

6. Provide group collaboration on model building and analysis: Yes ☐ No ☐ **(I)**
(e.g., can nodes be added as "sub-models" created by another user?)

Attachment 7

Questionnaire Response Raw Data

Tool Name: Analytica
Website: www.lumina.com
Company's Name: Lumina Decision Systems, Inc

General Features

1. Cost: **Professional $1295, Enterprise $2495, ADE $6000 (see Web site for lower prices until Nov 21 2003). 15% discount on 10+ licenses 25% discount on 50+ licenses.**

2. Maturity of the tool: **Mature. First released 1996, now in release 3.0**

3. Targeted Industries: **General: including technology, aerospace, consumer, defense, healthcare, energy & environment, higher education**

4. Major clients: **Thousands. See www.lumina.com/ana/customers.htm**

5. Type of Operating system supported: **Windows 95, 98, NT 4.0, 2000, XP, Mac OS up to 9.2**

6. Recommended Hardware:
   a. Processing power: **Pentium or later, or Power PC**
   b. RAM: **64MB**
   c. Other: **Color XGA screen**

7. Architecture support:
   a. Client – Server Model: Yes ☒ No ☐
   b. Desktop: Yes ☒ No ☐

Additional Comments: **Client-server model supported by Analytica Decision Engine. User must write end-user code. Analytica Web Publisher with automatically generated Web-based client user-interface expected release Q1 2004.**

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☒ No ☐
   c. Both Bayesian Nets and Influence Diagrams: Yes ☒ No ☐

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. From databases(i.e. Structure Learning): Yes ☐ No ☒
   c. Other:

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☐
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐

4. Conditional Probability Table:
   a. Specify Tables: Yes ☒ No ☐
   b. Specify Equations: Yes ☒ No ☐
   c. From databases (learn from training sets): Yes ☐ No ☒
   d. Other: **Can provide general functional form of relations, including procedures to generate probability distributions**

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Monte Carlo and Latin Hypercube**

7. Analysis techniques provided: **Many, including parametric sensitivity, correlation importance analysis, optimization. Note that Analytic can handle dynamic models (variables changing over time) without having to replicate nodes for time period. This makes it vastly easier to build, faster to evaluate, and simpler to understand dynamic models than competing methods.**

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☒
    a. If yes, explain:

Additional Comments: **Analytica is designed for and extremely versatile and efficient for forward or causal reasoning with influence diagrams. It is limited for backward or diagnostic reasoning.**

Performance and Extensibility

1. Language used to develop:
    a. GUI: **C++**
    b. Computational Engine: **C++, Analytica scripting**
2. Is source code available to the end user: Yes ☐ No ☒
3. Is the API available to the end user: Yes ☒ No ☐
4. Availability of the tool's performance measurement: Yes ☐ No ☒
    a. If yes, please indicate the procedure in measuring the performance:
5. Maximum Nodes a single model can support: **Tens of thousands, each with multidimensional values, comparable to millions for conventional representations**
6. Error recovery support: Yes ☒ No ☐
    a. If yes, explain: **Extensive diagnostic and error handling, including the ability to continue execution with partially undefined or infinite values. Interpretive mode makes it easy to find problems. Execution profiling (in Enterprise version) supports model optimization.**

Additional Comments: **Analytica provides its own general scripting language, which is very powerful especially for multidimensional modeling. Some users who want to do substantial diagnostic inference use Analytica UI to create models and export to Winbugs to evaluate them.**

Interoperability

1. Ability to interface with databases: Yes ☒ No ☐
    a. If Yes,
        i. Using ODBC: Yes ☒ No ☐
        ii. Databases it can interface directly with (list them): **Any that supports ODBC**
    b. Does it support SQL interface: Yes ☒ No ☐
    c. Can the models be saved to a database: Yes ☒ No ☐
2. Format used to the save the model: **XML file format**
3. Export the model to other applications: Yes ☒ No ☐
    a. If yes, list the applications the model can be exported to: **Databases and editors that support XML. Model may also be edited in any word processor.**
4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
    a. If Yes, list applications that it can be exported to: **Can copy and paste, or OLE hotlink tables and graphs to Microsoft Excel, Powerpoint and many other common Windows applications. Can use Excel seamlessly for graphing results. Can save table results into tab-delimited files for viewing and analysis in Excel or most statistical and database packages.**
5. Tools uses open standards: Yes ☒ No ☐

6. Provide group collaboration on model building and analysis: Yes ☒ No ☐

Additional Comments: **Multiple users can collaborate in building models, and can distinguish inputs and scenarios by multiple users or experts by indexing.**

Additional Notes: **Each variable or node in Analytica can represent a single value (number or text) or a multidimensional table. This facility, along with its Intelligent Array capabilities provide great convenience, flexibility, and speed for scaling up to handle large "industrial-scale" problems.**
See www.lumina.com/casestudies for sample applications

Tool Name: BayesBuilder
Website: http://www.mbfys.kun.nl/snn/nijmegen/index.php3?page=31
Company's Name: Smart Research BV

General Features

1. Cost: **2000 Euro per license for GUI only. 4000 Euro per license including API**

2. Maturity of the tool: **4 years**

3. Targeted Industries: **BayesBuilder was constructed for a research project that aimed to build a large scale model for medical diagnostics.**

4. Major clients: **Our main commercial client is SKF. They used BayesBuilder+ API to build a web-based diagnostic system for bearing failure analysis. See http://evolution.skf.com/gb/article.asp?articleID=471**

5. Type of Operating system supported: **Win32 Release for Windows 95, Windows 98 and Windows NT (4.0) - or higher - on Intel hardware.**

6. Recommended Hardware:
   a. Processing power: **Pentium or faster**
   b. RAM:**32 megabytes**
   c. Other: **22 Mb on harddisk; Minimum desktop areafor GUI: 800x600 pixels. Color palette: 256 colors, VGA.**

7. Architecture support:
   a. Client – Server Model: Yes ☒ No ☐
   b. Desktop: Yes ☒ No ☐

Additional Comments: **for client server model, one needs to purchase the API (a library of JAVA calls). API runs independently of GUI.**

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☐ No ☒
   c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☒

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. From databases(i.e. Structure Learning): Yes ☐ No ☒
   c. Other: **via API (i.e. JAVA)**

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☒
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☒

4. Conditional Probability Table:
   a. Specify Tables: Yes ☒ No ☐
   b. Specify Equations: Yes ☐ No ☒
   c. From databases (learn from training sets): Yes ☐ No ☒
   d. Other:

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **junction tree**

7. Analysis techniques provided: **(1) standard conditioning of variables, and (2) computer of correlations and cross entropy between pairs of variables.**

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☒
    a. If yes, explain:

Additional Comments:

Performance and Extensibility

1. Language used to develop:
    a. GUI: **JAVA**
    b. Computational Engine: **C++**
2. Is source code available to the end user: Yes ☐ No ☒
3. Is the API available to the end user: Yes ☒ No ☐
4. Availability of the tool's performance measurement: Yes ☐ No ☒
    a. If yes, please indicate the procedure in measuring the performance:
5. Maximum Nodes a single model can support: **no built in constraint- depends on complexity of the graph (clique size limited to 20) . Several hunderds of nodes run smoothly. I expect 3000 to 10000 nodes is feasible in sparse models, but I never tested this.**
6. Error recovery support: Yes ☐ No ☒
    a. If yes, explain: **Java error messages**

Additional Comments:

Interoperability

1. Ability to interface with databases: Yes ☐ No ☒
   a. If Yes,
      i. Using ODBC: Yes ☐ No ☒

      ii. Databases it can interface directly with (list them):

   b. Does it support SQL interface: Yes ☐ No ☒
   c. Can the models be saved to a database: Yes ☐ No ☒

2. Format used to the save the model: **text file (ASCII), possibly encrypted. Other save formats are not supported.**

3. Export the model to other applications: Yes ☐ No ☒
   a. If yes, list the applications the model can be exported to:

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
   a. If Yes, list applications that it can be exported to: **gif, jpeg**

5. Tools uses open standards: Yes ☒ No ☐
   a. If yes, explain: **inference is standard junction tree (with the complete-neighbour heuristic for constructing the junction tree)**

6. Provide group collaboration on model building and analysis: Yes ☐ No ☒

Additional Comments:

Additional Notes: **an unrestricted GUI-version can be downloaded free of charge to evaluate BayesBuilder. See webpage at the beginning of the questionnaire. This version contains a tutorial and a manual of the tool.**

Tool Name: BayesiaLab
Website: www.bayesia.com
Company's Name: Bayesia S.A.

General Features

1. Cost: **For about 10-60 licenses or is their a group license, etc**

   1 License: 3450 Euros

   5 Licenses: 10 350 Euros

   10 Licenses: 17 250 Euros

   50 Licenses: 43 125 Euros

2. Maturity of the tool: **BayesiaLab is on the market since 2002, but the first version of the tool has been initially realized in an academic research center in 1998**

3. Targeted Industries: **Industrial companies, Consulting companies, Information Technology companies, Pharmaceuticals companies, Research centers and Universities**

4. Major clients: **EDF, Saint Gobain, Cap Gemini Ernst&Young, Sumitomo Pharmaceuticals, Parks Canada, CNRS**

5. Type of Operating system supported: **All the OS having a Java Virtual Machine**

6. Recommended Hardware:
   a. Processing power: **>=1 Ghz**
   b. RAM: **>=256**
   c. Other:

7. Architecture support:
    a. Client – Server Model: Yes ☐ No ☒
    b. Desktop: Yes ☒ No ☐

Input Manipulation

1. Type of Network support:
    a. Bayesian Networks: Yes ☒ No ☐
    b. Decision Networks/Influence Diagrams: Yes ☒ No ☐

    When going thru the tutorial, I did not see any discussion on whether BayesiaLab supports decision node type. I did realize that it supports the concept of Cost. Is this what you had in mind when you answered Yes for the above question? Can BayesiaLab support decision node types?

    Indeed, BayesiaLab supports two kinds of costs: a cost for knowing the value of a variable (useful for the adaptive questionnaires) and utility nodes that allows qualifying states defined by node value combinations. But, we have not implemented the so called decision nodes. We manage such nodes with probabilistic nodes (with action as modality) to evaluate policies.

    c. Both Bayesian Nets and Influence Diagrams: Yes ☒ No ☐

2. Model Building capability:
    a. Using GUI: Yes ☒ No ☐
    b. Other: Using a custom language, batch mode etc
    c. From databases (i.e. Structure learning): Yes ☒ No ☐

3. Type of graph support:
    a. Only Undirected graph: Yes ☐ No ☒
    b. Only Directed graph: Yes ☐ No ☒
    c. Chain graphs (i.e. mixed undirected and directed): Yes ☒ No ☐

4. Conditional Probability Table:
    a. Specify Tables: Yes ☒ No ☐
    b. Specify Equations: Yes ☒ No ☐
    c. From databases (learn from training sets): Yes ☒ No ☐
    d. Other: **deterministic mode**

i. **Deterministic mode => if a node is logical and, or, etc deterministic mode allows for this logical representation.**

Does BayesiaLab support Noisy-or nodes?

It is possible to quickly define a CPT thanks to the Noisy-Or-Function that is available in the equation editor but we don't have specific Noisy-Or nodes.

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Junction tree, Likelihood weighting**

   Does BayesiaLab support both causal and diagnostic inference? Also, does the user have a choice to decide which type of inference algorithm (exact or stochastic) to use?

   Yes, you can do inference in any directions, from symptoms to causes, from causes to symptoms and any combination of these inferences. The inference menu allows you choosing between the exact and approximate inference.

   Does BayesiaLab support negative and likelihood evidence (like Hugin and Netica)

   Yes, for both exact and approximate inference.

7. Analysis techniques provided:

   *** Arc Analysis: allows highlighting the importance of the arc with respect to the complete structure. The thickness of the arc is proportional to the importance of the probabilistic relation it represents in the total probability law.**

   *** Target Node Analysis: allows the visualization of the quantity of information brought by each node for the knowledge of the target node. The brightness of the squares appearing inside the nodes is proportional to this quantity of information**

   *** Target Modality Analysis: allows visualizing, for each node, two kinds of information relative to the target: the type of the probabilistic relation binding this variable and the target variable, and the information gain brought by each**

node for the knowledge of the modality of the target node

*** Target Analysis Report: Textual report describing the context of the analysis (list of the variables that are observed when the analysis is carried out), the probability distribution of the target variable knowing the context, a list of nodes, sorted by descending order according to their relative contribution to the knowing of the target variable (the nodes that do not bring any information do not appear in this list), for each value of the target, list of nodes, sorted by descending order according to their relative contribution to the knowing of the target value (if the node has only two modalities, this list is identical to the preceding one), for each influencing node, description the modal value with respect to the context and to the observed modality of the target node (this modal value comes with its probability, this section allows establishing the profile of this target value), for each influencing node, description of the modal value when the target node is unobserved (but knowing the context, that makes it possible to define the profile when the target variable is unobserved), and a measure indicating the variation between the modal values of the two profiles. This value is measured only when these values are identical. A positive value indicates then an information gain to the knowledge of the node value when the target value is observed.**

*** Adaptive Questionnaires: This functionality allows the automatic and dynamic activation of the monitors of the variables that bring information on the probability distribution of the target variable at lower cost. The monitors are sorted according to their relevance (ratio between information gain in the current context and the cost implied for knowing the value of the variable).**

*** Questionnaire based on the knowledge of a particular value of the target variable: This functionality, similar to the previous one, differs only by the measurement of the information gain. This gain is no longer measured according to the total probability distribution of the target variable, but is completely centered on the knowledge of a particular value**

*** Causal analysis thanks to the equivalence classes. Arcs that can be reversed without changing the probability law are undirected. It is then possible to choose an orientation that is automatically propagated to the network**

(orientation of the compelled arcs, update of the conditional probability tables).

8. For tools using Bayesian Networks (Ref. Col B data) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☐
    a. If yes, explain: **I don't understand if you are speaking about building the networks through data mining or if you are speaking about inference in large Bayesian networks. In the first case, our learning methods are all based on the Minimum Description Length score (equivalent to having an automatic threshold in the constraint based approaches for determining statistical independence). Concerning inference, it is indeed impossible to construct the junction tree for large networks that are highly connected. In that case, on has to use the approximate inference.**

Thru this question, we were trying to find out if the tool has the capability to limit its inference based on the type of evidence provided. For example, given an evidence for a certain node, the tool know that it does not have to update the entire net, but only update a sub-section of the net that will be effected by this evidence. Does BayesiaLab have such a feature?

Not for the moment.

Performance and Extensibility

1. Language used to develop:
    a. GUI: **java**

    b. Computational Engine: **java**

2. Is source code available to the end user: Yes ☐ No ☒

3. Is the API available to the end user: Yes ☒ No ☐

4. Availability of the tool's performance measurement: Yes ☒ No ☐

Thru this question, we wanted to know if you had any results on performance (time it took to do inference) of the tool for some "typical problems". Do you have any results that show the performance of the tool for any problems that you have modeled and used?

Indeed we have such results on benchmarks but only for learning (scientific publications on our learning algorithms), but not for inference.

a. If yes, please indicate the procedure in measuring the performance: **The first global performance measure is the MDL score available thanks to the console. Otherwise, BayesiaLab offers various tools for measuring the performance when specifying a target node :**

*** Total precision of the model: number of correct predictions of the value of the target variable / number of cases in the data base**

*** Confusion matrix: the total precision is useful but can be too general. The Confusion Matrix proposed by BayesiaLab allows having a more precise feedback about the model performances: reliability (i.e. the rate of correct prediction for each value given by the model), precision (the rate of detection for each value of the base)**

*** Lift curve: represents the detection rate of the target value (Y-axis) with respect to the number of processed cases (X-axis) based on the order defined by the model. Allows choosing the best threshold to reach a particular rate of detection**

*** ROC curve: True Positive Rate (Y-axis) against the False Positive Rate (X-axis). Allows choosing the best threshold to reach a particular ratio between true and false positives.**

5. Maximum Nodes a single model can support: **As I said it before, it is difficult to give a maximum number of nodes since it depends also on the number of node values. However, last week, I have worked on a genetic data base containing 2000 columns with 3 modalities for each gene on a 1 GHz PC with 256 MO without problem.**

6. Error recovery support: Yes ☒ No ☐
    a. If yes, explain: **Exceptions throwned by the Java Virtual Machine are catched and it is possible to automatically send the error message to Bayesia so that we can correct the error. If the exception is relative to memory, a specific window explain what parameters have to be change to allow BayesiaLab to work with more memory.**

Interoperability

1. Ability to interface with databases: Yes ☐ No ☒
    a. If Yes,
        i. Using ODBC: Yes ☒ No ☐
            1. If Yes, list the data bases the ODBC driver supports:

        ii. Databases it can interface directly with (list them):

    b. Does it support SQL interface: Yes ☒ No ☐
    c. Can the models be saved to a database: Yes ☐ No ☒

2. Format used to the save the model: **XBL, a specific format based on XML. BayesiaLab can also read BIF and NET networks.**

3. Export the model to other applications: Yes ☐ No ☒
    a. If yes, list the applications the model can be exported to:

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
    a. If Yes, list applications that it can be exported to: **It is possible to paste the monitors to any applications that interact with the clipboard of the OS. Monitors can be pasted as texts, arrays or images.**

5. Tools uses open standards: Yes ☒ No ☐

   a. If yes, explain: **Bayesian Interchange Format (BIF)**

6. Provide group collaboration on model building and analysis: Yes ☒ No ☐

Can you please explain how group collaboration is supported?

We have two tools that help working in collaboration on model building:

1. It is possible to associate color tags to nodes in order to group them visually and to ease the brain storming with the domain experts.
2. Its is possible to associate hypertext comments (with links to files or http address) to the network (by default the Author name and creation date) and to each node (to describe the role of the node, to increase the traceability, to justify the probabilities, to associate illustrations, schemas, …)

Additional Notes: **BayesiaLab also offers:**

*** Complete wizards for importing data bases with complete missing value processing (filtering, replacing with given values, structural Expectation-Maximization), filtering capabilities (variables and values), intelligent discretization tools, database transposition (e.g. for the micro-array data processing).**

*** Possibility to generate cases with respect to the current network**

*** Possibility to save the database as associated to the current network, i.e. with its treatments (discretization, filtering, missing values processing)**

*** Complete structural learning toolbox: three unsupervised learning methods to discover all the probabilistic relations that hold in the database, five supervised learning methods to characterize a target variable (from naïve to markov blanket learning), and clustering methods that allow to segment the data. All these learning algorithms support missing values.**

*** Hidden variables: it is possible to add hidden nodes, i.e. nodes that have not data in the database and to combine them manually/automatically with the others.**

*** Possibility to do structural learning from an existing network (a priori knowledge), and to fix the arcs so that the learning algorithm cannot change this knowledge.**

*** Batch exploitation: Possibility to use the current network to do an off line tagging of the cases contained in a database.**

*** Complete Dynamic Bayesian Networks processing to introduce the temporal dimension in the model (step by step simulation, period simulation, probability evolution in a graph that can be printed or saved, and possibility to associate an observation file). Possibility to use a time node, i.e. a parameter node that represents the time and that can be directly used in the equations describing probability distributions.**

*** Constraint nodes: Boolean nodes that are always observed and that are used to express constraints between nodes**

*** Automatic positioning of the nodes**

*** Warning tags on the nodes that have a not a filled conditional probability table**

*** Error tags on the nodes that have an incorrect equation due to parent modifications**

*** Hypertext comments on the networks and the nodes**

*** Color tags on the nodes to group them semantically.**

*** Special monitors for the numerical nodes that give the mean and the standard deviation and that have three display modes (normal, relative and relative + curve)**

*** Possibility to display the delta (probability variation) on the monitor between each evidence introduction/removal**

*** Possibility to specify costs to each node, i.e. the cost implied for knowing the value of the nodes (useful for the adaptive questionnaires)**

*** Possibility to set an image background (a map, a logo, ...)**

Tool Name: OCCAM – Organizational and Cultural Criteria for Adversary Modeling
Website: http://www.cra.com
Company Name: Charles River Analytics, Inc.

General Features

General Note:

The following questionnaire pertains mainly to Bayesian network technology which is only one part of our intelligence operations decision-aiding system. In addition, our system allows the user to construct and fire rules using a commercial, off-the-shelf rule engine and editor. Both the rules and belief networks are able to interact with the various entities represented in our tool (e.g., cultural stereotypes, organizations, individuals). In addition, our primary display, the social network, allows the user to quick identify individuals, groups, and events (and the relationships among these) to run these rules and belief networks on. The application level data is stored in a database, mapped onto a domain model, and then operated on by rules and/or belief networks in a unified fashion via our inference engine user interface.

1. Ease of use:

- Is there feedback for processing delays? **For most types of delays, yes (e.g., for rule/BN processing)**
- Do menu items and text descriptions use language that is commonly understood? **Yes**
- Are menu items in standard places? Are layouts, terms, icon screen positions, windows, dialog boxes consistent? **Yes**
- How many steps does it take to perform a frequently used action (desire not buried in menus; not multi-step)? **It depends on the action – many actions are tied to short-cut keys. Furthermore, some actions are tied to multiple user interface elements (e.g., a toolbar button, a short-cut key, and a pull-down menu item) to promote both ease-of-use and ease-of-learning.**
- Do you show user that he/she has made a mistake? How is user aided in correcting mistakes? **It depends on both where in the system the mistake is made and what type of mistake is made.**
- Do you visually display system objects, actions, and options to users or are these available textually? How do you aid users' memory for these choices? Are instructions easily available if the user forgets or loses his/her way? **Both toolbars and menus are used to present available actions, objects, preferences, etc. ToolTips are available for all toolbar items.**
- Does your system cater to novice and expert users? Allow users' to create shortcuts for frequently used actions? **The system does cater to both novice and expert users (in particular, by providing explanatory interfaces and visualizations to the novice, and more sophisticated editing and deductive reasoning tools to the expert). We don't currently allow users to dynamically generate shortcuts, but we provide them ourselves (e.g., ctrl-a selects all, ctrl-s saves, etc.)**
- How is help and/or documentation provided to the user? **Tooltips provide additional help on all actions and in some displays. Help menu functionality exists, but full technical documentation is still underway.**
- How does your software handle making best use of limited screen "real estate"? **Use of information rich displays coupled with extensive use of scrollbars and split-screens maximize screen "real estate".**
- Top 5 "trouble" reports? **N/A**

2. Cost: Seat license; upgrades; support; maintenance; (for government customer)

   Proprietary

3. Maturity of the tool: (Number of years in the market, # versions/upgrades)

   Components of the tool have been under development for 5+ years, other components are the result of more recent (past 2 years) research and development efforts.

4. Targeted Industries:

   Proprietary

5. Major clients:

   Proprietary

6. Type of Operating system supported: List all applicable OS

   WindowsXP and Windows2000, currently, plans to expand to Unix platforms in the future.

7. Recommended Hardware: (list both minimal and optimal)
   a. Processing power: **P4 1.6+**
   b. RAM: **512 MB**
   c. Other:

8. Architecture support:
   a. Client – Server Model: Yes ☐ No ☒
   b. Desktop: Yes ☒ No ☐

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☐ No ☒
   c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☒
   d. Decision Trees: Yes ☐ No ☒

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. Other: Using a custom language, batch mode etc
   c. From databases (i.e. Structure learning): Yes ☐ No ☒

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☒
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☒

4. Conditional Probability Table:
   a. Specify Tables: Yes ☒ No ☐
   b. Specify Equations: Yes ☐ No ☒

   (not currently available within the CPT editor, but full cut and paste capability to/from Excel is supported)

   c. From databases (learn from training sets): Yes ☒ No ☐ **(supports fully observable and partially observable data sets)**
   d. Other: **Various other proprietary user interface techniques**.

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used:

   Hugin Junction Tree Algorithm (not product, just algorithm)

7. Analysis techniques provided/supported: List and explain

   Mutual information sensitivity analysis

8. For tools using Bayesian Networks (Ref. Col B data) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☒

   a. If yes, explain:

Performance and Extensibility

1. Language used to develop:

   a. GUI: **Java**

   b. Computational Engine: **Java (for both rules and BNs)**

2. Is source code generally available to a government end user: Yes ☐ No ☒

(If no, is there any circumstance where the source code could be made available?)

This would have to be negotiated.

3. Is the API available to the end user: Yes ☒ No ☐

4. Availability of the tool's performance measurement: Yes ☐ No ☒

   a. If yes, please indicate the benchmark/procedure used to measure performance:

5. Maximum Nodes a single model can support: (Max nodes a model can support when running on the recommended system)

Only limited by CPU and memory. On the recommended system, on the order of 10^3 (but still depends on network density).

6. Error recovery support (if something crashes, what happens?):

Use last saved state (no intermediate or auto-save features currently implemented)

Interoperability

1. Ability to interface with databases: Yes ☒ No ☐ **(The application supports SQL queries to retrieve data used as evidence in the networks. Also, the rule engine component can store rules in a database. Bayesian network component receives data from the database via the domain model of the main application.)**
    a. If Yes,
        i. Using Open Data Base Connectivity (ODBC): Yes ☒ No ☐
            1. If Yes, list the data bases the ODBC driver supports: **the JDBC 2.0 bridge used supports the ODBC 2.x and ODBC 3.x driver manager and drivers, so any database that supports those standards**
        ii. Databases it can interface directly with(list them): **anything compatible with the JDBC/ODBC bridge**
    b. Does it support SQL interface: Yes ☒ No ☐
    c. Can models created in the tool be saved to a database: Yes ☒ No ☐ **(not Bayesian networks, the application level data is saved in a database and any ruleset may also be stored in a database)**

2. Format used to the save the model: **xbn (standard xml BN format) for BNs proprietary ruleset format for rules**

3. Export the model to other applications: Yes ☒ No ☐
    a. If yes, list the applications the model can be exported to:
    Any application that will read the common xbn format.
    Rulesets are not currently exportable

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
    a. If Yes, list applications that it can be exported to:
    This feature is currently under development:
    BNs: the model can be exported to any application that reads xbn files
    Rules: the model cannot currently be exported

Domain model: the model is stored in a database accessible via SQL queries Also, results of analysis can be captured in standard image formats (e.g., JPEG, GIF)

5. Tools uses open standards: Yes ☒ No ☐
   a. If yes, explain: **In the BN model: save model to xbn files (xml bnet stadard), cut/paste CPT entries to/from Excel. In the domain model: SQL syntax for querying data in domain model**

6. Provide group collaboration on model building and analysis: Yes ☐ No ☒

Tool Name: DXpress Solution Series
Website: www.kic.com
Company's Name: Knowledge Industries, Inc.

General Features

1. Cost: **To be negotiated - depends upon user domain, degree of exclusivity and usage. Some domains are not available for license.**

2. Maturity of the tool: **Fully mature software developed since 1992, no changes to the Inference Engine since 1999 and only minor editing for the editor and testing segments. No outstanding trouble reports, in daily heavy commercial usage for web-based interactive diagnostic applications. First sales in 1993.**

3. Targeted Industries: **The initial version was designed for medical diagnosis. The current software has been developed to be domain independent and has been used in aerospace, metals manufacturing, medical clinics, locomotive repair, automotive repair, internal auditing and community relations as well as proprietary applications..**

4. Major clients: **The Knowledge Industries' client list is proprietary and will be disclosed as appropriate. It includes Fortune 100 firms as well as start-up companies.**

5. Type of Operating system supported: **Microsoft W2000, NT4.0, XP**

6. Recommended Hardware:
   a. Processing power: **500 mhz or greater**
   b. RAM: **Inference Engine - 1.4 MB, Compilier - 5.7 MB, Test System - 2.5 MB**
   c. Other: **Sufficient disk space to store the Bayesian Knowledge Databases. Each Bayes network is compiled by DXpress and is stored as an Object (file) that can be executed by either WIN-DX for test and validation purposes or operated by the API/dll that resides within the**

End User's application. We refer to these in the collective as the Knowledge Databases.

Can you please explain what you mean by Bayesian Knowledge Databases?

7. Architecture support:
   a. Client – Server Model: Yes ☒ No ☐
   b. Desktop: Yes ☒ No ☐

Additional Comments: **There are three separate modules. DXpress is the Editor/Compilier, Win-DX is the test and validation module and API/dll is the Inference Engine that executes the compiled Bayes network. Standard practice is to develop and test on the desktop and upload to the Inference Engine running on a server. The Inference Engine (API/dll) is state-free.**

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☐ No ☐
   c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☐

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. From databases(i.e. Structure Learning): Yes ☐ No ☒
   c. Other: **There is a graphics editor for building the Bayes Network.**

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☐
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐

4. Conditional Probability Table:
    a. Specify Tables: Yes ☒ No ☐
    b. Specify Equations: Yes ☐ No ☒
    c. From databases (learn from training sets): Yes ☐ No ☒
    d. Other: **There currently is no direct method of connecting external sources of Conditional Probabilities to the CP tables. Such a feature has been designed and can be added if needed. All CP tables entries must be completed prior to compilation. Incomplete information is not allowed.**

   Is there support for Noisy-Or nodes (if a child node has a large parent set)?

   Yes

   Does DXpress support negative and likelihood evidence? (Like Hugin and Netica)

   I'm sorry; I have not examined either of these packages in enough detail to respond. I do not know what is meant by negative and likelihood evidence as opposed to Conditional Probabilities. I suspect that this is a result of differences in nomenclature, not capability.

5. Validity of the model:
    a. Consistent Probability check of variables in the net: Yes ☒ No ☐
    b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Proprietary, to be discussed under conditions of confidentiality as needed.**

   Is it based on any standard junction tree algorithms that are generally applied to Bayesian Nets? Also, does DXpress support both exact and approximate inference algorithms?

   A response to this question will be forthcoming.

7. Analysis techniques provided: **Execution of the network may be coded directly into the system so that, depending upon the state of an input variable, entire segments of the network will be deemed "not applicable" and will not be examined - i.e., yes.**

For this question, I was thinking along the lines of Sensitivity analysis or Importance analysis – where the user selects a node (target node) and wants to find out how the other nodes in the network impact it. Does DXpress provide such support?

Ah ha! Yes, we have what we call a "debug" function that allows the elicitor to identify selected nodes to be "debug" nodes and a complete sensitivity analysis can be made during the test and validation phase of BBN construction using WIN-DX.

Where is this debug function? Also, when you mean by sensitivity analysis during using WIN-DX , are you referring to how the beliefs in the possible disorders changes based on the evidence entered.

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☒ No ☐
    a. If yes, explain: **The technology is proprietary.**

Additional Comments: **Value of Information is used.**

Performance and Extensibility

1. Language used to develop:
    a. GUI: **C++**

    b. Computational Engine: **C++**

2. Is source code available to the end user: Yes ☐ No ☒

3. Is the API available to the end user: Yes ☒ No ☐

4. Availability of the tool's performance measurement: Yes ☒ No ☐

a. If yes, please indicate the procedure in measuring the performance: **Load testing.**

I am not clear on what you mean by Load testing? For this question, we want to know if you have done any performance measurements of DXpress for some set of problems. If so, are the results available?

A licensee performed load tests prior to selecting our software. In Summary form – on a 455 MHz computer using a large Bayes Network (over 200 nodes) and instantiated with all input simultaneously the test system processed over 1,000 transactions per minute with no measurable delay.

5. Maximum Nodes a single model can support: **Performance limit has not been established, however, 400-node, multi-fault networks have been built and operated. In general, the limitation on node number is the ability of the developer(s) to understand the resulting network at a deep level. We have found that for a team of experienced elicitors, an effective limit of 400 nodes per network applies. We solve the large network problem by a domain division method. For example, in one major application of over 700 networks, the applicable network is selected by a meta-network.**

6. Error recovery support: Yes ☒ No ☐
   a. If yes, explain: **Not a clear question in this context. Each module has operational diagnostics. Do you refer to the Inference Engine? The Editor/Compilier?**

We want to find out what kind of error recovery support the tools provides to the user when developing the model and running inference on it. Say, if I am constructing a model, does the tool have a built in feature to auto-save the model every x units of time, so if my system crashes, there is a way to recover the last saved version?

We do not have automatic "save" implemented. The User must save the BBN as it is developed.

For API, what kind of Error recovery support is provided? – are the error messages well documented?

We think the error messages from the API are well documented – but none of our clients have reported any error messages in the last four years of heavy commercial usage of the API.

When running the inference algorithm, does the tool let the user know if it ran out of memory?

We have never had this problem. Our inference system depends upon a pre-compiled BBN in contrast to interpretive systems, the API is optimized for a small footprint and even the largest of the BBNs that we have tested (over 400 nodes) will run on a Pentium I computer with limited memory.

Additional Comments:

Interoperability

1. Ability to interface with databases: Yes ☒ No ☐
   a. If Yes,
      i. Using ODBC: Yes ☐ No ☐
      ii. Databases it can interface directly with (list them): **The potential exists, but has not been implimented.**

   I have noticed that DXpress does not support structure learning (true) and conditional probability learning (true). So, if this feature is implemented, will it useful only to save the Bayesian net models to databases directly (we do save our compiled networks and they could easily be placed into a database system).

   No, we would allow the importation of Conditional Probability tables from external sources to modify an existing BBN.

   b. Does it support SQL interface: Yes ☐ No ☒.
   c. Can the models be saved to a database: Yes ☒ No ☐

2. Format used to the save the model: **Proprietary.**

3. Export the model to other applications: Yes ☐ No ☒
    a. If yes, list the applications the model can be exported to: **All file formats are proprietary.**

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
    a. If Yes, list applications that it can be exported to: **Any**

    Can you please list some of the applications?

    We routinely export files from the Test and Validation module (WIN-DX) to Excel and other similar programs in a comma-delimited format to allow graphic display of the individual Case that is being evaluated.

5. Tools uses open standards: Yes ☐ No ☒
    a. If yes, explain:

6. Provide group collaboration on model building and analysis: Yes ☒ No ☐

Additional Comments: **Has had extensive use by a team building over 700 networks for automotive diagnosis.**

Additional Notes: **Software is industrial-strength, runs all of the time and runs well, handles both single fault and multiple fault Bayes networks and is feature rich. Well suited for human elicitation and can be readily adapted for automation of conditional probabilities from external sources. See www.Symptomedix.com for an interactive diagnostic for headaches. Note that the sequence of the questions in the demonstration is based upon all prior inputs and that the diagnosis becomes stable after the first 8 to 12 of the 150+ inputs have been requested.**

Tool Name: Ergo
Website: www.noeticsystems.com/ergo
Company's Name: Noetic Systems Incorporated

General Features

1. Cost: **$200 GUI, $100 run-time library; volume discounts are available**

2. Maturity of the tool: **Developed and maintained since 1989; no bug reports for version 1.0 (GUI or API) for over 1 year.**

3. Targeted Industries: **Experts in any field who want to transfer their expertise to a computer-based expert system**

4. Major clients: **Licensees include Cisco Learning Institute, General Electric, Educational Testing Service, dozens of university/academic licensees in North America, Asia, and Europe**

5. Type of Operating system supported: **GUI: Macintosh, Windows.**
   Run-time API: Macintosh, Windows, Unix

6. Recommended Hardware:
   a. Processing power: **No minimum**
   b. RAM: **1Mb**
   c. Other: **Disk space: 1 Mb**

7. Architecture support:
   a. Client – Server Model: Yes ☐ No ☒
   b. Desktop: Yes ☒ No ☐

Additional Comments:

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☐ No ☒
   c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☒

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. From databases(i.e. Structure Learning): Yes ☒ No ☐
   c. Other: **From scripts (i.e., replay network-construction events)**

   How can it do structure learning when there is no support for database interface?

   Replay network-construction events??? Explain

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☐
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐

4. Conditional Probability Table:
   a. Specify Tables: Yes ☒ No ☐
   b. Specify Equations: Yes ☐ No ☒
   c. From databases (learn from training sets): Yes ☒ No ☐
   d. Other:

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Proprietary version of Lauritzen-Spiegelhalter; user can also enter likelihood ratios as evidence; inference can be performed in batch mode for validation, from GUI or API**

7. Analysis techniques provided: **Batch processing; log file**

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☒
    a. If yes, explain:

Additional Comments: **Client-server architecture and database connectivity are under development.**

Performance and Extensibility

1. Language used to develop:
    a. GUI: **C++**

    b. Computational Engine: **C++; API has C or C++ interface**

2. Is source code available to the end user: Yes ☐ No ☒

3. Is the API available to the end user: Yes ☒ No ☐

4. Availability of the tool's performance measurement: Yes ☐ No ☐
    a. If yes, please indicate the procedure in measuring the performance:

5. Maximum Nodes a single model can support: **Limited by available memory; maximum number of conditional probabilities per node is 2^32**

6. Error recovery support: Yes ☒ No ☐
    a. If yes, explain: **GUI and API return error codes for all errors/warnings**

Additional Comments:

Interoperability

1. Ability to interface with databases: Yes ☐ No ☒
   a. If Yes,
      i. Using ODBC: Yes ☐ No ☐
      ii. Databases it can interface directly with (list them):
   b. Does it support SQL interface: Yes ☐ No ☒
   c. Can the models be saved to a database: Yes ☐ No ☒

2. Format used to the save the model: **Proprietary binary (more efficient); text; XML**

3. Export the model to other applications: Yes ☒ No ☐
   a. If yes, list the applications the model can be exported to:

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
   a. If Yes, list applications that it can be exported to: **GUI saves graph to clipboard for export to drawing programs**

5. Tools uses open standards: Yes ☐ No ☒
   a. If yes, explain:

6. Provide group collaboration on model building and analysis: Yes ☐ No ☒

Additional Comments:

Additional Notes: **Inference based on docking has also been implemented. This advance supports the decomposition of a network into diagnostic (system) and evidence subnetworks; evidence subnetworks are "docked" to the diagnostic module when they are instantiated, leading to greatly reduced computational**

complexity for the diagnostic module, without loss of accuracy as occurs for stochastic-inference methods. Please see the following reference for more information:

Almond RG, Herskovits EH, Mislevy RJ, Steinberg LS. Transfer of information between system and evidence models. Heckerman D and Whittaker J (Eds.). Proceedings of the Seventh International Workshop on Artificial Intelligence and Statistics, 1999, pp. 181–186. San Francisco: Morgan Kaufmann.

Tool Name: Hugin Developer
Website: www.hugin.com
Company's Name: Hugin Expert A/S

General Features

1. Cost: **Please see price quote separately**

2. Maturity of the tool: **Hugin API - 13 years - Hugin GUI - 10 years**

3. Targeted Industries: **Medical industy - this was the starting industry - now as Hugin is a general purpose tool, we aim at many different industries.**

4. Major clients: **Please see our reference list. Note: No reference list provided.**

5. Type of Operating system supported: **Windows, Unix, Linux**

6. Recommended Hardware:
   a. Processing power: **1 GHz**
   b. RAM: **256 Mb**
   c. Other:

7. Architecture support:
   a. Client – Server Model: Yes ☐ No ☒
   b. Desktop: Yes ☒ No ☐

Additional Comments: **Hugin API compiles with ansi C, and the Hugin GUI requires Java. It is Hugins policy to be open for the requirements of the customers. If a customers e.g uses another operating system that the mentioned ones, we are open for this. It only requires that the customer makes the operating system available to Hugin for compiling.**

Input Manipulation

1. Type of Network support:
    a. Bayesian Networks: Yes ☒ No ☐
    b. Decision Networks/Influence Diagrams: Yes ☒ No ☐
    c. Both Bayesian Nets and Influence Diagrams: Yes ☒ No ☐

2. Model Building capability:
    a. Using GUI: Yes ☒ No ☐
    b. From databases(i.e. Structure Learning): Yes ☒ No ☐
    c. Other:

3. Type of graph support:
    a. Only Undirected graph: Yes ☒ No ☐
    b. Only Directed graph: Yes ☒ No ☐
    c. Chain graphs (i.e. mixed undirected and directed): Yes ☒ No ☐

4. Conditional Probability Table:
    a. Specify Tables: Yes ☒ No ☐
    b. Specify Equations: Yes ☒ No ☐
    c. From databases (learn from training sets): Yes ☒ No ☐
    d. Other: **Supports missing information**

5. Validity of the model:
    a. Consistent Probability check of variables in the net: Yes ☒ No ☐
    b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Hugin Propagation - a.k.a junction tree propagation**

7. Analysis techniques provided: **Conflict analysis**

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☒
    a. If yes, explain:

Additional Comments: **3.a - easily corrupted**

Performance and Extensibility

1. Language used to develop:
    a. GUI: **JAVA**

    b. Computational Engine: **C**

2. Is source code available to the end user: Yes ☐ No ☒

3. Is the API available to the end user: Yes ☒ No ☐

4. Availability of the tool's performance measurement: Yes ☒ No ☐
    a. If yes, please indicate the procedure in measuring the performance: **Please see page 8, 9 and 16 in the attached slides. Note: No slides provided.**

5. Maximum Nodes a single model can support: **RAM limited only, please see page 8 and 9 in the attached slides. Note: No slides provided.**

6. Error recovery support: Yes ☒ No ☐
    a. If yes, explain: **All functions set error code**

Additional Comments: **C++,VB,JAVA: Throw/Catch Mechanism**

Interoperability

1. Ability to interface with databases: Yes ☒ No ☐
    a. If Yes,
        i. Using ODBC: Yes ☒ No ☐

        ii. Databases it can interface directly with (list them): **Oracle 8 i**

    b. Does it support SQL interface: Yes ☐ No ☒
    c. Can the models be saved to a database: Yes ☐ No ☒

2. Format used to the save the model: **NET, HKB**

3. Export the model to other applications: Yes ☒ No ☐
    a. If yes, list the applications the model can be exported to: **B-course, Genie, Samiam**

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☒ No ☐
    a. If Yes, list applications that it can be exported to: **BMP**

5. Tools uses open standards: Yes ☐ No ☐
    a. If yes, explain: **All major Algorithms published, ANSI C (API)**

6. Provide group collaboration on model building and analysis: Yes ☐ No ☒

Additional Comments:

Additional Notes: **In general Hugin are open towards special customer needs and wishes. This means that if our customers needs any further functionality which not are implemented in the standard product, we are willing to consider**

this as a new functionality, or we are able to offer consultancy to the customer in order to develop and implement a special feature in our standard product.

Tool Name: PSYOP PT
Website: www.mtisurv.com/psyopdemo
Company Name: Metrica, Inc.

General Features

1. Ease of use:

- Is there feedback for processing delays? **Yes**
- Do menu items and text descriptions use language that is commonly understood? **Yes**
- Are menu items in standard places? Are layouts, terms, icon screen positions, windows, dialog boxes consistent? **Yes**
- How many steps does it take to perform a frequently used action (desire not buried in menus; not multi-step)? **1 or 2 steps**
- Do you show user that he/she has made a mistake? How is user aided in correcting mistakes?
- Do you visually display system objects, actions, and options to users or are these available textually? How do you aid users' memory for these choices? Are instructions easily available if the user forgets or loses his/her way? **Yes**
- Does your system cater to novice and expert users? Allow users' to create shortcuts for frequently used actions? **Mainly to novice users.**
- How is help and/or documentation provided to the user?
- How does your software handle making best use of limited screen "real estate"? **Scrolling and user options to reduce font size.**
- Top 5 "trouble" reports?

2. Cost: Seat license; upgrades; support; maintenance; (for government customer)

3. Maturity of the tool: Number of years in the market, # versions/upgrades.

4. Targeted Industries: Business, medical, govt.,etc. **US Armed Forces**

5. Major clients: **US Air Force Air Intelligence Agency**

6. Type of Operating system supported: List all applicable OS

   Server: Windows NT 4.0 or higher; Client: Any machine capable of running Internet Explorer 5.0 or higher.

7. Recommended Hardware: (list both minimal and optimal)
    a. Processing power: **200Mhz or Higher**
    b. RAM: **24 Mb (dependant on OS)**
    c. Other: **Server software required IIS 4.0 or higher**

8. Architecture support:
    a. Client – Server Model: Yes ☐ No ☐ **Yes.**
    b. Desktop: Yes ☐ No ☐ **Yes, if the desktop has Microsoft PWS or IIS installed.**

Input Manipulation

1. Type of Network support:
    a. Bayesian Networks: Yes ☐ No ☐
    b. Decision Networks/Influence Diagrams: Yes ☐ No ☐
    c. Both Bayesian Nets and Influence Diagrams: Yes ☐ No ☐
    d. Decision Trees: Yes ☐ No ☐

2. Model Building capability:
    a. Using GUI: Yes ☐ No ☐ **Yes**
    b. Other: Using a custom language, batch mode etc
    c. From databases (i.e. Structure learning): Yes ☐ No ☐

3. Type of graph support:
    a. Only Undirected graph: Yes ☐ No ☐
    b. Only Directed graph: Yes ☐ No ☐
    c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐

4. Conditional Probability Table:
    a. Specify Tables: Yes ☐ No ☐
    b. Specify Equations: Yes ☐ No ☐
    c. From databases (learn from training sets): Yes ☐ No ☐
    d. Other: Other Input techniques used

5. Validity of the model:
    a. Consistent Probability check of variables in the net: Yes ☐ No ☐
    b. Cyclic Dependency structure check among variables: Yes ☐ No ☐

6. Inference Algorithm used: List all relevant algorithms

7. Analysis techniques provided/supported: List and explain
   ® MAUT as evidenced by SMART, and regression based policy specifying

8. For tools using Bayesian Networks (Ref. Col B data) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☐ No ☐
    a. If yes, explain:

Performance and Extensibility

1. Language used to develop:
    a. GUI: **Active Server Pages, VBScript**

    b. Computational Engine: **Active Server Pages, VBScript**

2. Is source code generally available to a government end user: Yes ☐ No ☐ **Yes**
   (If no, is there any circumstance where the source code could be made available?)

3. Is the API available to the end user: Yes ☐ No ☐ **No**

4. Availability of the tool's performance measurement: Yes ☐ No ☐ **No**
    a. If yes, please indicate the benchmark/procedure used to measure performance:

5. Maximum Nodes a single model can support: Max nodes a model can support when running on the recommended system **No hard limits. Only limited by physical memory.**

6. Error recovery support (if something crashes, what happens?): **Software automatically saves inputs as the user works. So, if a system failure occurs, the user can pickup exactly where they left off.**

Interoperability

1. Ability to interface with databases: Yes ☐ No ☐ **Yes**
    a. If Yes,
        i. Using Open Data Base Connectivity (ODBC): Yes ☐ No ☐ **Yes**
            1. If Yes, list the data bases the ODBC driver supports:
            MS Access

        ii. Databases it can interface directly with(list them): **None**

    b. Does it support SQL interface: Yes ☐ No ☐ **Yes**
    c. Can models created in the tool be saved to a database: Yes ☐ No ☐ **Yes**

2. Format used to the save the model: **???**

3. Export the model to other applications: Yes ☐ No ☐ **No (?)**
    a. If yes, list the applications the model can be exported to:

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☐ No ☐ **No**
    a. If Yes, list applications that it can be exported to: Eg: PPT, Word, JPEG, PDF format, PS format, etc

5. Tools uses open standards: Yes ☐ No☐ **???**
    a. If yes, explain:

6. Provide group collaboration on model building and analysis: Yes ☐ No ☐ **Yes**
    (e.g., can nodes be added as "sub-models" created by another user?) **No**

Tool Name: Netica
Website: www.norsys.com
Company's Name: Norsys Software Corp.

General Features

1. Cost: **Single licenses: $585 for GUI, $685 for API. Site licenses available for 5 times as much. API embedded is $20 to $175 depending on volume.**

2. Maturity of the tool: **In development since 1992; sold since 1995**

3. Targeted Industries: **Industrial diagnosis, financial risk management, enviromental planning, decision analysis, user modeling.**

4. Major clients: **Exxon, Boeing, AIG Risk Finance, Lockheed Martin, Electricité de France, CIA, MIT, Stanford, Motorola, NASA, SAIC, Siemens, Rockwell, US Navy, Northrop Grummon, Raytheon and many others (see www.norsys.com/clients.htm)**

5. Type of Operating system supported: **Windows 95 to XP, MacOS, and API for Linux, Sun Solaris and HP-UX.**

6. Recommended Hardware:
   a. Processing power: **Practical with 200 MHz but large models require more**
   b. RAM: **Practical with 128 MB but large models require more**
   c. Other:

7. Architecture support:
   a. Client – Server Model: Yes ☒ No ☐
   b. Desktop: Yes ☒ No ☐

Additional Comments:

Input Manipulation

1. Type of Network support:
   a. Bayesian Networks: Yes ☒ No ☐
   b. Decision Networks/Influence Diagrams: Yes ☒ No ☐
   c. Both Bayesian Nets and Influence Diagrams: Yes ☒ No ☐

2. Model Building capability:
   a. Using GUI: Yes ☒ No ☐
   b. From databases(i.e. Structure Learning): Yes ☐ No ☒
   c. Other: **Currently adding structure learning**

3. Type of graph support:
   a. Only Undirected graph: Yes ☐ No ☐
   b. Only Directed graph: Yes ☒ No ☐
   c. Chain graphs (i.e. mixed undirected and directed): Yes ☐ No ☐

4. Conditional Probability Table:
   a. Specify Tables: Yes ☒ No ☐
   b. Specify Equations: Yes ☒ No ☐
   c. From databases (learn from training sets): Yes ☒ No ☐
   d. Other: **Sequential updating, and missing data can be handled by the EM learning or gradient descent algorithms**

5. Validity of the model:
   a. Consistent Probability check of variables in the net: Yes ☒ No ☐
   b. Cyclic Dependency structure check among variables: Yes ☒ No ☐

6. Inference Algorithm used: **Several, mainly junction tree (aka known as join tree or clique tree). Logic sampling.**

7. Analysis techniques provided: **Sensitivity to findings (mutual information, variance reduction, etc), Testing the net for accuracy with a database of**

cases, "Processing" sets of cases using the network, "Summing-out" sections of the network, noisy-or, noisy-and, noisy-max and noisy-sum nodes

8. For tools that support Bayesian Networks (Ref. Question 1) are there built in methods to trim the network or otherwise limit computational complexity with "relevance reasoning" or any other method: Yes ☒ No ☐
    a. If yes, explain: **Sensitivity analysis, "summing out" parts of the network**

Additional Comments:

Performance and Extensibility

1. Language used to develop:
    a. GUI: **C++**
    b. Computational Engine: **C++**
2. Is source code available to the end user: Yes ☒ No ☒
3. Is the API available to the end user: Yes ☒ No ☐
4. Availability of the tool's performance measurement: Yes ☒ No ☐
    a. If yes, please indicate the procedure in measuring the performance: **Test for prediction or diagnosis accuracy against a database of cases: Error rate, logarithmic loss, Brier score, confusion matrix, surprise matrix, ROC curves, etc.**
5. Maximum Nodes a single model can support: **No limit; Easily handles 1000s if the graph structure is simple.**
6. Error recovery support: Yes ☐ No ☐
    a. If yes, explain:

Additional Comments: **Extensive effort has been put into error checking, and recovering well.**

Interoperability

1. Ability to interface with databases: Yes ☒ No ☐
    a. If Yes,
        i. Using ODBC: Yes ☒ No ☐

        ii. Databases it can interface directly with (list them): **Windows ODBC databases, such as MS Access**

    b. Does it support SQL interface: Yes ☒ No ☐
    c. Can the models be saved to a database: Yes ☐ No ☒

2. Format used to the save the model: **DNE, NETA, can also read several other formats, such as Ergo, DX Express, Hugin. XML implemented but not yet available.**

3. Export the model to other applications: Yes ☐ No ☐
    a. If yes, list the applications the model can be exported to: **Some other programs can read Netica format, but we don't have any experience or knowledge of how well.**

4. Ability to export results/graphs generated from the "what-if" scenarios or the analysis: Yes ☐ No ☒
    a. If Yes, list applications that it can be exported to: **Nice graphics of the net can be copied and pasted into Microsoft office products. Tables of conditional probabilities and inference results can be pasted into Excel or a text file (or read from them).**

5. Tools uses open standards: Yes ☐ No ☐
    a. If yes, explain:

6. Provide group collaboration on model building and analysis: Yes ☐ No ☒

Additional Comments:

DARPA's Wargaming The Asymmetric Environment (WAE) Program

What is WAE's mission? The mission of the WAE program is to develop and demonstrate models and tools "tuned" to specific adversaries, thus enabling analysts and decision-makers to better anticipate, predict, and act against those who threaten U.S. and Allied interests. Asymmetric adversaries, for WAE's purpose, span the continuum from guerrilla warfare as experienced in the Balkans to the present terrorist threat. The resultant technology will yield an automated Continuous Indication and Warning System composed of multiple group-specific predictive models (FY 04).

What are WAE's research questions? The research questions for WAE are numerous and include at a high level; do pre-incident indicators exist that provide relevant predictions of our adversaries' future behavior? If predictive pre-incident indicators exist, what predictive fidelity do they possess? Can these pre-incident indicators predict the timeframe, target, direction of interest, or tactical characteristics of future attacks? What is the shelf life of these pre-incident indicators? Can these pre-incident indicators provide any insight into how to influence these adversaries? As quick disclaimer, WAE's technology does not possess the ability to predict the specific day, time, target address, and method of an attack. However, WAE does contend that prediction of an adversary's behavior is possible at a detail level that at a minimum dramatically increases the specificity of the indication and warning space. The metrics for assessing WAE's success are straightforward; the predictive technology is frequently validated against both historical information and real-time information.

How does WAE's approach differ from the current analytical approach? WAE's approach is vastly different from the current analytical approach and supporting technologies. This difference is best articulated in an analogy of attempting to predict the behavior of an electronic circuit of unknown design contained within a black box. The current analytical method and tools will attempt to re-create the design of the circuit within the black box; understanding the major components and their respective interactions. WAE's approach, on the other hand, concentrates on the environment external to the black box, specifically the input and output behaviors. Thus WAE's approach is to derive the behavioral transform function by analyzing the relationship between the input and output signals across a range of inputs. The result is a transfer function that predicts the circuit behavior without replicating the circuit design.

Why is this approach important? This approach is important for three reasons. First, WAE's approach provides reliable predictions of near-term future behavior (continuous indication & warning) while the existing detection approach and technology, at best, provides a description of recent past behavior. Second, WAE's approach uses a different and more readily available information base than current detection approaches and can thus derive predictive models when detection approaches falter. An example of this is the Greek terrorist organization referenced in the results table above. This group operated for 27 years without the US intelligence community knowing any group members. Without knowledge of the group members, the US intelligence information consisted largely of forensic information. WAE's approach derived pre-incident

indicators that were stable for the early, middle and final years of this group. Third, the pre-incident indicators that drive WAE's predictive models are in form that is consistent with and usable by the information operations community, with the added benefit of also provided observable metrics.

What are WAE's predictive results? WAE has derived models of a number of asymmetric groups in conjunction with our operational partners. WAE's validates its predictive models through both historical and real-time tests against the operation target. An example of WAE's initial results is represented by recent tests of a predictive model of a specific European Terrorist organization. The model was derived from a training set of attacks and non-attacks that spanned the life of this organization. The results are presented here as the percentage of correct predictions along two dimensions. First is the fidelity of the attack characteristics: attack/no attack, target, direction of interest, and tactical characteristics. The second is the predictive accuracy, true positive and true negative. True positive, for example, represents the percentage of correct predictions that the *next attack* would reflect the nature of each attack characteristic. Conversely, true negative represents the percentage of correct predictions that the next attack would not reflect the nature of each attack characteristic. For example, if the model predicts the next attack is against a US asset, it is also predicting the next attack will not be against the Host, Adjacent, or other International countries.

As you can see the results are high across the board and in fact, from a statistical perspective, the predictive accuracy for each attack characteristic is significant well beyond the traditional $p<.01$ criteria. What is clear, at least for this group, is the existence of discernable, predictive patterns to their behavior at a level specific enough to support the indication and warning process. The signatures clearly distinguish between the environmental conditions preceding an attack versus no attack, a civilian versus a military target, a privately owned versus a publicly owned target, and an attack on a U.S. versus NATO target. Furthermore, the results indicate that the fixed set of signatures is predictive over the life of this group as well as over the evolution of this group's tactical capability.

Unclassified - FOUO

Predictive Results

- **European Terrorist Group I**
  - Historical test on 82 attacks
  - Modeled group behavior. Did not use data on specific group members, money or logistics
- **Testing**
  - Model derived on a training set of attack & non-attack data spanning the life of the organization
  - Model tested on a separate but equivalent data set
- **Results**
  - Predictions of each response are statistically significant
  - Predictions are stable over life of group
  - Predictions are stable over the group's tactical evolution

Next Attack

	True +	True -
Attack	99%	93%
No Attack	93%	99%

Next Target

Civilian	100%	100%
Military	100%	100%
Private	89%	80%
Public	80%	89%

Next Direction of Interest

U.S.	86%	93%
Host	93%	100%
Adjacent	75%	99%
International	67%	95%

Next tactic

Direct Fire	78%	88%
Indirect Fire	46%	82%
Bombing	68%	73%

Unclassified - FOUO

Who are WAE's operational partners? Since its inception (2000), WAE has worked cooperatively with DoD and the intelligence community to develop and demonstrate predictive models and tools "tuned" to specific adversaries, thus enabling analysts and decision-makers to better anticipate, predict, and act against those who threaten U.S. and Allied interests. Our partners include the Joint Information Task Force for Counter Terrorism (JITF-CT), the Joint Staff J3 - Deputy Director for Information Operations (J39), and the Joint Information Operations Center. These partnerships range from supporting an on-site WAE team that works closely with analysts to develop and test predictive tools to providing independent review of predictive results and technologies. As a result, WAE and the operational community have developed technologies that derive group specific pre-incident indicators of impending attacks, converted these pre-incident indicators into predictive models, and then validated the predictive model against both historical and real-time information. As a result of these successful tests, operational partners such as the JITF-CT are working with WAE to further test and transition the predictive models and tools into their analytical process.

Attachment 8

The Mitre Corporation Report

REPORT OF

A MARKET SURVEY AND RESEARCH ON

TIME LINE ANALYSIS TOOLS

31 AUGUST 2002

PREPARED FOR:

The MITRE Corporation
Center for Integrated Intelligence Systems
7515 Colshire Drive
McLean, Virginia 22102-7508

PREPARED BY:

Information Management Solutions (G066)
Information Technology Center (ITC)
Center for Integrated Intelligence Systems (CIIS)

Jerry Cogle, Senior Advisor
John Wigle, Principal Researcher
Jennifer Webster, Researcher

Letter of Transmittal

Mr. Glen Nakamoto
The MITRE Corporation
202 Burlington Road (Rte. 62)
Bedford, Massachusetts 09071

September 1, 2002

Dear Mr. Nakamoto,

Please find enclosed the final report of the Market Research Survey for Time Line Analysis Tools in response to the research proposal accepted by your office. We have prepared the final report in softcopy in two formats for inclusion in your Knowledge Portfolio and the MITRE IT Advisor as you requested.

Thank you for the opportunity to conduct this research on behalf of The MITRE Corporation. I am looking forward to working with your office on future efforts of the knowledge portfolio.

Respectfully,

John Wigle, G066

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Executive Summary

Since September 11, 2001 the needs of the United States Intelligence Community (IC) have increased for time line analysis to assist with counter-terrorism analysis and the Asymmetric Order of Battle (ASOB) problem. MITRE does not have in-depth experience with time line analysis tools as evidenced by their lack in the MITRE Analysis Tool Shed and other internal analytic tool collections. Currently, the IC is in the process of identifying new signatures and methods of detecting and predicting terrorism. Time line analysis is and will be an important tool in combating terrorism and the Asymmetric Order of Battle (ASOB) problem.

To better understand the capabilities of time line analysis tools, and how they support the counter-terrorism mission; the MITRE Information Technology Center (G060) initiated an internal time line analysis tool study. This MITRE study was conducted during the summer of 2002. The MITRE study team's first step was to meet with several MITRE and U.S. Government intelligence analysts and collect a set of functional requirements for a time line analysis tool. Using these requirements the study team performed a market survey of available products that may meet some or all of the requirements. The study performed a paper comparison of the tools followed by vendor demonstrations and requests for demonstration time line analysis to be added to the MITRE Analyst Tool Shed. The results of the study are summarized by a scored comparison matrix of the best time line analysis tools currently available.

Based upon the requirements, the MITRE study team's research, and the information provided by the vendors, our recommendation is i2's Analyst Notebook version 6. It was the most intuitive, was verified to have had most of the high-level requirements, and had helpful documentation. The i2 staff was also very helpful and quick to respond to questions and support. Unfortunately it was not due out until the end of the 2002 calendar year.

The other highly ranked tool to examine closely would be VisualLinks by Visual Analytics. And finally, watch for a Windows release of CaseTrak III by Badge 1022 Software. The tool remained promising, and showed well for a shareware product.

I. OVERVIEW

1.1 Background

Since September 11, 2001, the analytical needs of the United States Intelligence Community (IC) have increased to identify new signatures[1] and methods of detecting and predicting global terrorism. There are many areas of automated analysis, including entity extraction, text mining, categorization, summarization, and search and retrieval[2]. However time line analysis has been largely overlooked. At the time of printing, time line analysis tools remained a weak point among the MITRE capability as evidenced by the MITRE Analyst Tool Shed.[3]

After 9/11 several customers engaged in operational analysis requested MITRE to integrate analytical tools into their environments and requested easy to use tools[4]. Among the areas requested in automated analysis was time line analysis. Additionally, several MITRE analysts and an engineer[5] were interested in various automated tools, including time line analysis. It became apparent very quickly that time line analysis was an important tool in combating the Asymmetric Order of Battle (ASOB) problem. Additionally, we discovered that every analyst had a different need and was grappling issues with different levels of complexity ranging from simple to robust. Having tools at varying degrees of complexity would be critical to providing the most effective means of automated analysis[6].

The Information Technology Center core technology program funded this study. The performance of this study was part of the ITC's Knowledge Portfolio Program (MITRE Information Intranet link: http://g060.mitre.org/network_site/index.html).

1.2 Objectives

Through market research and evaluation of time line analysis tools, explore the current state of affairs in the time line analysis market to better enable MITRE to respond to the analytical community, and to provide the analytical community a better range of tools from which to select an automated solution. Specifically to:

- Determine the high-level automated tool requirements of analysts
- Find new time line analysis tools not listed in the MITRE Analysis Tool Shed
- Evaluate tools against the requirements identified by the analysts.

[1] Jerry Cogle. "Timeline Analysis Tools." E-mail to Julie Gravallese and Glen Nakamoto. 22 March 2002.
[2] Glen Nakamoto's Transfer Folder - Knowledge Portfolio <http://transfer.mitre.org/STF40-49/42/13742/Transfer/Knowledge%20Portfolio/Products/TopicMapCollaborationWebPresentation/doc/PKM_Export-195.htm> August 31, 2002
[3] Analysis Tool Shed home page. <http://idia.mitre.org/toolshed/index.htm> August 31, 2002.
[4] Mark Maybury. "Re: Timeline Analysis Tools." E-mail to Jerry Cogle, Rod Holland, and John Griffith. 01 April 2002.
[5] Tom Carroll (G073), Barry Costa (G051) and Tom McEntee (G075)
[6] Time Line Analysis Market Research and Investigation Proposal. G066 dated March 22, 2002.

1.3 Approach

The study team met with and interviewed two analysts from The MITRE Corporation[7] and from the U.S. Government[8]. The analysts interviewed represented a variety of analysis disciplines with over 80 years of combined experience. From these interviews the study team developed high-level requirements for time line analysis tools.

The interviews conducted were primarily focused on identifying the manual processes used that did not incorporate computers or other automated processes. This methodology was employed so that analysts, who are not currently using automation, had the opportunity to express their needs and desires for an ideal computer application. By deriving requirements from the analyst's perspective, the study team hopes to achieve acceptance from all analysts in the use of the tools evaluated meeting the stated requirements.

The evaluation of tools was based on the high level requirements identified in the next session. We developed an Excel spreadsheet detailing the high level requirements, what we looked for within that high level requirement, and indicated for each tool whether it met the requirements or not. The vendors were contacted and given a copy of the high level requirements and asked to comment on them, and provide a demo or evaluation copy of their tool. The study team made a concerted effort to confirm the vendor's remarks on their tool's ability to satisfy the stated requirements through direct demonstration of the tool's capability.

In the event a vendor did not respond to our inquiries, the study team did their best to evaluate the demo without the vendor's assistance. And if the study team was unable to verify the capability through a demo or evaluation copy, then the vendor's remarks were relied upon as truthful but were notated that they were unconfirmed. If the vendor neither responded nor provided a direct demonstration of the capability to the team, then the tool is considered not evaluated for this report.

1.4 High Level Requirements

The very basic requirement for this research effort was a software utility or tool that was able to produce a time line with associated information to allow the user to conduct meaningful analysis, assessments and connections. The study team used the expounded requirements as a means of creating the Tools Comparison Chart. The high level requirements for a time line analysis tool provided by the intelligence analysts were:

Table 1 - High Level Requirements

1	Automation of input from various sources and in various formats.
2	Save the customized method of data import for reoccurring formats.
3	Save bibliographical data references, kind of events, dates and times for events and

[7] Carroll, Tom (G073) and McEntee, Tom (G075). Personal interviews. 5 April 2002 and 26 April 2002, respectively.
[8] Unidentified intelligence analyst of the US Government. Personal interview. 30 April 2002. And an unidentified, Special Agent with the US Department of Agriculture, Criminal Investigation Unit. Personal interview. 14 May 2002.

	entities.
4	Comment on an event or entity, analogous to a post-it® note.
5	Query events and entities by time, date, references, and kind of event.
6	Place events on multiple threads.
7	Gantt chart known problems to reverse engineer events.
8	Move events around time line.
9	Expand and/or compress time line.
10	Categorize events with icons.
11	Export to various formats, including power point, MS word, Visio, web, PDF.
12	Output to large plotter devices
13	Has an intuitive and user-friendly interface.

1.5 Meanings Used for High-Level Requirements

Automation of input from various sources was divided into three areas, manual, semi-automatic and dynamic. Manual meant the user selected the appropriate menu items to initiate a manual process of importing data from a source into the tool. Semi-automatic meant the tool had a wizard-like interface that assisted the user with importing data. Dynamic meant there existed a facility to connect to other data sources similar to ODBC or XML, etc.

Saving customized data import formats was referred to as a filter. A filter was defined as a tool's ability to remember the data format. Similar to an XML DTD, or an ODBC driver, the tool could understand the data being imported once an appropriate filter was selected. The Department of Defense (DoD) Regulations[9] requires all DoD intelligence agencies to have the ability to understand SGML, HTML, and XML for data exchange and interoperability. If a tool was ODBC or XML enabled, it was presumed to have met the first two high-level requirements.

Saving bibliographical data references, kind of events, dates and times for events and entities was broken down into bibliographical, time, date, and references. The bibliographical data meant the analyst would be able to see the evidence or citation to raw intelligence establishing the event or entity. The kind of event meant the user would be able to make a notation of the type of event, like a drug transaction, wire transfer, phone call, etc. and is named references in the second column of the Tool Comparison Chart. Time and date are self explanatory, except that it was important for analysts to be able to leave dates blank if they did know when an event occurred.

The Post-it® note requirement was liberally construed to include tools that had the ability to place a text box next to an event, or place a comment or note in the event itself.

Querying events and entities by time, date, references and kind of event meant the tool had the ability to sort, select or only list events or only list entities matching the search criteria. The meaning of references for this high-level requirement was semantically

[9] DoD Joint Technical Architecture version 4, dated 17 July 2002, § 2.2.2.1.4.1, "Document Interchange" <http://www-jta.itsi.disa.mil/jta/JTA40_071702.pdf>

different from high-level requirement number 3. In this requirement, references meant bibliographical references. The search criteria had to allow the user to search by the four areas defined, whether the tool used a sort, a select or a listing. The four areas defined were time, date, references, and type of event.

Placing events on multiple threads meant the tool had the ability to display several time lines or parallel activities on the same time domain or display.

The ability to Gantt chart known problems to reverse engineer events meant the tool had the ability to place events into an alternate view showing tasks or threads, schedules or timelines and their dependencies like a Gantt chart.

Moving events around the time line meant a user could directly manipulate an event to either expand/compress the time line on each side the event, or that the event could be moved vertically along a horizontal time line to facilitate spatial or other notation for the analyst.

To expand and/or compress time line meant the user could universally define several different scales along the same time line.

Categorize events with icons meant that the user had the ability to select and assign meaningful icons for events and entities. Icons were liberally construed to include photographs in JPEG and GIF format or clip art in addition to traditional icons.

Exporting to various formats, including Microsoft Power Point, Microsoft Word, Visio, web, and PDF meant precisely that except web meant any of the formats commonly used on the Internet to exchange documents and graphics. The formats for the web specifically included, HTML, JPEG, GIF, and text.

To ensure coverage by DoD and non-DoD agencies and components, tools were further examined to see if they could read from major data sources like Oracle, Microsoft Excel, Sybase, Microsoft Access, Informix, Ingress, and Microsoft SQL Server[10].

Output to large plotter devices meant that the tool was capable of working with larger printer devices like a D-size plotter with the appropriate windows drivers installed on the system, or at least was able to tile the chart on regular printer size paper so it could be assembled into a large chart.

Had an intuitive and user-friendly interface was a subjective requirement, but the study team did its best to be objective. User friendly and intuitive meant that the tool did not require the user to open the help files and manuals too often. Specifically, if a tool was determined *not* to be intuitive then it meant the tool did not follow the Microsoft Windows graphical user interface standards or had significant problems preventing the user from completing tasks.

[10] Joint Technical Architecture List of Mandated and Emerging Standards, dated 17 July 2002 <http://www-jta.itsi.disa.mil/>

1.6 Scoring

Vendors provided information on the high level requirements, and study team members evaluated the tools individually and notes were compared and discussed. There were three scores associated for each tool. They were the requirements score, the confidence score and the overall score. Each score is normalized between 0 and 10 with zero meaning very poor and 10 meaning outstanding. The requirement score was computed by adding up the total number of defined requirements satisfied, then dividing it by the total number of defined requirements. The total number of defined requirements was twenty-six (26). Then multiplying it by 10 for a normalized score.

The confidence score ranked the study team's level of confidence in the information they had about the tool. If the study team was unable to verify if a requirement was satisfied, then a "not reported" is shown for the defined requirement on the Tool Comparison Chart. However, if the vendor asserted they met the requirement, but the study team was unable to verify the fact, then a "yes†" or "no†" is listed with a caveat that it was considered satisfied only based upon the vendor's statements without verification by the study team. The confidence score is computed by totaling the number of defined requirements not verified by the study team, then subtracting that number from the total number of defined requirements and multiplying the result by 10 to normalize the score.

Two products, VisualLinks and TimeMap, had the vendor statements listed. The study team inquired late with the makers of VisualLinks about the high-level requirements and a request for an evaluation copy. There was sufficient time to conduct a cursory review of their tool, but the vendor prevented the study team from beginning an evaluation. The vendor had a very iterative customer service process in obtaining the answers to the requirements, then for permission to download an evaluation copy, then to obtain a password, and finally a server demo license key[11]. TimeMap was revisited following feedback on the final report and vendor statements were added to the matrix.[12]

The overall score is simply computed by adding the requirements score with the confidence score, and again was normalized by dividing by 2. This system of scoring is far from perfect but provides a reasonable way to compare the tools with one another and this type of method closely matched the study team's expert judgment[13].

[11] Lynee Weston, Visual Analytics. "RE: New Client Profile for jwigle@mitre.org" E-mail to John Wigle. 29 August 2002.
[12] Bob Wiss, Casesoft Software. Telephone Interview. 8 October 2002.
[13] Dr. Lehner (G06A). Meeting on expert judgment for National Intelligence Priorities Framework. 29 July 2002.

II. EVALUATIONS

2.1 Tools Investigated

The tools were found by using the MITRE Analyst Tool Shed and search engines over the Internet. The tools evaluated were:

- ***TimeMap* by Case Soft**
- ***WebTAS* by Air Force Research Labs, Rome, NY**
- *Watson* by Xanalys
- *Orion VIA* by Orion Scientific Systems
- *Analyst Notebook* by i2 Inc
- *Pen-Link Analysis Software* by Pen Link
- *CaseTrak III* by 1022 Badge Software
- *VisualLinks* by Visual Analytics

2.2 Discussion on Evaluated Tools

A total of eight tools were evaluated for the market survey and research project. Tools appear in the same order as the Tool Comparison Chart. The discussion covers the tool's rank, strengths, weaknesses, customer support and a recommendation. Unique attributes or special considerations of the tool were included for completeness.

2.2.1 TimeMap

TimeMap developed by Case Soft sells for an affordable $199 per desktop. It was designed to work with companion products CaseMap and TextMap used by law firms, private practice attorneys, and prosecutors to prepare their cases for litigation in court. CaseSoft had also sold site licenses to the Department of Justice and Department of Defense Criminal Investigation communities[14]. TimeMap was a simple way to make a timeline out of known events[15]. It scored an overall 7.7 in a 3rd place tie with the Watson tool. It was above average on meeting requirements with a score of 6.5. It was easy to learn, can be self taught or taught by demo over the telephone[16]. It was one of the few tools that had a Gantt chart and plotter capability, along with better than average ability to export to other formats. TimeMap had a semiautomatic method for importing data from CaseMap, which in-turn could semi-automatically populate from TextMap[17]. It lacked an ability to query against the time line. It could not import data from other sources automatically for populating a timeline but simply makes one out of events manually inputted[18]. Expect good customer support. They were quick to respond, had demonstration software on their website, and were helpful in answering any questions. Recommended for analytical shops looking for modest capability at a modest price.

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[14] Thomas McEntee. "Re: Time Line Analysis Report..." E-mail to John Wigle. 29 September 2002
[15] Jeffrey Lisson, Attorney. "Evidence Analysis: Timelines Are Not Just for Trial Anymore" Legal Tech April 2002 Vol. 20, No. 1, Pg. 3.
[16] Jennifer Webster. "added info about casesoft..." E-mail to John Wigle. 29 August 2002.
[17] Thomas McEntee. "Re: Time Line Analysis Report..." E-mail to John Wigle. 29 September 2002
[18] Thomas McEntee. "CaseSoft Legal Software Applications". E-mail to John Wigle. 17 May 2002.

2.2.2 WebTAS

WebTAS developed by Air Force Research Labs (AFRL) was customized rapid development software. It was designed for government or large enterprise customers. It scored an overall 7.9 as the 2nd place tool. It was better than average on meeting requirements at a score of 6.2. It was one of the few tools that had a Gantt chart and could dynamically access other data sources. WebTAS was looked at heavily as an import system that automatically put events on time lines. There were some powerful capabilities, such as geographic mapping, that were not displayed by any commercial products. The events were highly searchable, but the learning curve was high to retrieve information. A two-day specialized training session was required at $1,535 just to begin working with this tool[19]. The manual was overly specific in some areas and vague in others[20]. The tool itself was not intuitive to use[21]. Its weaknesses were definitely an unfriendly interface, a lack of ability to export to other formats, and less annoying but simple features like placing comments or notes on events[22], and moving the events around on the time line. The study team and others at MITRE were unable to get WebTAS working[23], and relied on Janet Hitzeman's work with WebTAS to substantiate some of its capabilities[24]. Customer support from AFRL is weak. AFRL were no-shows at or cancelled several meetings with potential customers before[25]. It would be essential with this product to pay for and ensure software development, maintenance and user training were provided since this software would be built uniquely for each customer base. Recommend only for large shops with political clout and a large budget to support software development, maintenance and user training and to put pressure on AFRL if they fell behind in their support.

2.2.3 Watson

Watson developed by Xanalys was a commercial solution with an undisclosed price tag. It was designed for law enforcement, intelligence and government customers. It scored an overall 7.7 placing it in a 3rd place with TimeMap. It was above average on meeting requirements with a score of 6.5. It was strong on user features and export formats. News reports claim it was the world's best analytical tool, and it was voted the best intelligence analysis tool by an international law enforcement association in 1999[26]. However, it did not support dynamic access to other data sources or filters to simplify manual data importing. Expect less than average customer support for this tool. There was no response to inquiries for pricing information and some requirements. Recommended for small to medium shops that can afford to pay for premium customer support if offered.

[19] Jay Jesse. "Re: WebTAS." E-mail to John Wigle. 09 February 2002.
[20] Janet Hitzeman. "Re: webTAS." E-mail to Patrick Jones. 11 April 2002. and see next foot note.
[21] Janet Hitzeman. "FW: WebTAS" E-mail to Michael Maskaleris. 03 May 2002.
[22] Janet Hitzeman. "FW: WebTAS" E-mail to Michael Maskaleris. 03 May 2002.
[23] Barry Costa. "Re: WebTAS." E-mail to Michael Maskaleris and John Wigle. 06 May 2002.
[24] John Griffith. "Re: Timeline Analysis Tools." E-mail to Mark Maybury, Jerry Cogle, Rod Holland, Janet Hitzeman, Michael Merideth, Julie Gravallese, Aaron Lesser, John Wigle and Glen Nakamoto. 01 April 2002.
[25] Herbert Mucks, WebTAS PM "RE: webtas." E-mail to John Wigle. 14 March 2002.
[26] PRLine – England. "Global Graphics Announces a Euro 5.1 Million Canadian Government Software Contract for Xanalys Inc." 2 November 2000.

2.2.4 Orion VIA

Orion VIA developed by Orion Scientific Systems offered this commercial solution originally developed in cooperation with the Defense Advance Research Projects Agency. It was designed as an automated intelligence analysis system, and was professed to be a fixture in the IC. It scored an overall 7.1 placing it in 5th place. It was average in meeting requirements with a score of 5.0. The tool offered a Gantt chart and large plotter capability, and dynamic import from other data sources. Its shortcomings were weak query capability against the time line, poor data export format, and no ability to save data filters to facilitate common data imports to the tool. Expect the average customer support from a commercial software vendor. Recommended for shops to review, but only use if it solves unique needs other tools do not address.

2.2.5 Analyst Notebook 6

Analyst Notebook 6 by i2 Incorporated was due out at the end of 2002, and was a commercial solution with $3388 price tag per license that includes 1 year of technical support. It was developed for the British IC, and had customers all over the world, including the United States[27]. We got a sneak peek look at the pre-release[28]. It scored an overall 9.0 taking first place by a significant margin. It was outstanding in meeting requirements with a score of 8.1, one of the highest on the evaluation. The tool offered a rich user feature set, rich data import capability, and an easy to use interface. It could import data or connect directly to third party databases[29] like Microsoft Access and Sybase through its I-Bridge product. Events were searchable, and useable for both time line analysis and link analysis. Icons were used on the time line and could be changed or customized. The manual contained help documentation that was very good for learning how to use the tool. Additionally, Analyst Notebook 6 had a robust Application Programming Interface (API) to allow customization of the tool if needed. Its weaknesses were a lack of a Gantt chart capability and a marginal export capability. Expect outstanding customer support from i2. It is no coincidence that Analyst Notebook scored a perfect score for confidence. The i2 team was readily accessible, ensured questions were answered, and were very patient with the study team's questions and needs. Recommended for any size shop that can afford the price tag and wants to get rolling quickly with their analytical efforts, and particularly valuable if the shop has access to various data sources.

2.2.6 Pen-Link Analyst

Pen-Link Analyst by Pen-Link LTD was a shareware and commercial product developed primarily for law enforcement working with warrant access to telephone conversations. The tool places phone calls on a time line to assist law enforcement officers investigating and building their cases. It scored an overall 4.2 placing it in last place. It

[27] PR Newswire. "i2 Inc. Wins $2M Federal Contract from FBI" 31 July 2001.
[28] i2 Analyst Notebook 6. Pre-release Symposium. The Key Bridge Marriot, Rosslyn, Virginia. 7 August 2002.
[29] PR Newswire. "War on Drugs, Terrorism to Benefit from i2 Inc.'s Groundbreaking Telephone Call Pattern Analysis Software." Financial News section. 13 March 2002.

was below average on meeting requirements with a score of 3.8. The tool was rich in user features, including a PDA version of the tool. The only weaknesses known was the lack of a Gantt chart capability. The tool ranked second to last on the confidence scale, and it was unclear if it supported a rich data import/export capability, Post-it® note capability, multiple threads, ability to manipulate events on the timeline, and the ability to have several scales on the same time line. Customer support is unknown as well, except it was not available on the weekend. Recommend for further consideration by shops that are law enforcement oriented.

2.2.7 CaseTrak III

CaseTrak III developed by Badge 1022 Software as shareware. It was designed for the law enforcement community users on a tight budget. It scored an overall 6.3 placing it, surprisingly, above two other commercial products. It was below average on meeting requirements with a score of 3.1. Its strength was in data references and query capabilities. Its weaknesses were that it was still a DOS based program, had poor data import/export capabilities, and no graphical interface. Customer support would be problematic for Badge 1022 Software, which was one person. However, we did receive customer support on a holiday weekend[30]. Not recommended at this time except for an occasional analyst who might find it useful. Badge 1022 Software is considering redevelopment on Windows[31]. If a Windows version is released it is recommended analytical shops revisit this practical tool.

2.2.8 VisuaLinks

VisuaLinks™ developed by Visual Analytics was offered as a commercial product for an undisclosed price tag. The vendor supports the law enforcement, intelligence[32], corporate[33] and government[34] communities. The tool scored an overall 5.4 placing it second to last. However, it scored a 9.2 on its vendor-declared ability to meet requirements. VisuaLinks was the link analysis and visualization software used for Joint Intelligence Virtual Architecture at the Defense Intelligence Agency[35]. The low overall score was a result of the study team's inability to evaluate the tool. Therefore, the confidence score was 1.5. The study team was able to verify from news sources that it did have an XML interface and ability to pull data dynamically[36]. Expect frustrating customer support for this tool. Although we inquired late with Visual Analytics, there was sufficient time to handle our request to evaluate the tool and respond to the requirements[37]. We did

[30] Larry Rife, Badge 1022 Software. "Re: CaseTrak III" E-mail to John Wigle. 31 August 2002.
[31] See previous footnote.
[32] PR Newswire. "VisuaLinks Chosen as Link Analysis Tool for Major DIA and DISA projects". Financial News 25 June 2002.
[33] PR Newswire. "Visual Analytics Expands International Base into Asia.". Financial News section 5 December 2001.
[34] PR Newswire. "Visual Analytics Inc Licenses Visual Data Mining Software for Use in Counter-Drug Operations". Financial News section. 8 November 2000.
[35] PR Newswire. "VisuaLinks Selected as Best-of-Breed System for Large-Scale U.S. Intelligence Program". Financial News section. 14 February 2002.
[36] Kyle Balluck. "Feds to Use VAI App in Drug War". Newsbytes 8 November 2000.
[37] John Wigle "Timeline analysis capabilities..." E-mail to Lynee Weston. 21 August 2002.

receive a response to the requirements[38], but we were unable to get the appropriate license keys and login information[39] to begin our evaluation of the tool within a week. Recommend analytical shops of any size consider this tool based on its requirement rating, but carefully test drive the tool and the customer support before investing your business processes in the tool.

[38] Lynee Weston. Visual Analytics. "FW: Timeline analysis capabilities…" E-mail to John Wigle. 26 August 2002.
[39] Lynee Weston. Visual Analytics. "RE: New Client Profile for jwigle@mitre.org" E-mail to John Wigle. 29 August 2002.

Table 2 – Tool Comparison Chart – Part 1 of 2

Product Information	Name	TimeMap	WebTAS 2.1	Watson 5.0	OrionVIA 1.0.3
	Company	Case Soft	Intelligent Software Solutions	Xanalys	Orion Scientific Systems
	Web Address	www.casesoft.com	www.webtas.com	www.xanalys.com	www.orionsci.com
	Phone Number	(949) 760-1845	(315) 330-7850	(781) 736-1949	(703) 917-6540
	Cost	$199/desktop	Customized software	not reported	not reported
	Requirements Score	6.5	6.3	6.5	5.0
	Confidence Score	8.8	9.5	8.8	9.2
	Overall Score	7.7	7.9	7.7	7.1
High Level Requirements	***Defined Requirements***				
Automation of input from various sources and in various formats.	**Manual Input**	yes	yes	yes	yes
	Semi-Auto Load	yes	yes	yes	yes
	Dynamic Access	yes†	yes	not reported	yes
Save the customized method of data import for reoccurring formats.	**Filters**	Only from CaseMap, TextMap	yes	not reported	not reported
Save bibliographical data references, kind of events, dates and times for events and entities.	**Bibliographical**	yes†	yes	no	not reported
	Time	yes	yes	yes	yes
	Date	yes	yes	yes	yes
	References	yes†	yes	yes	no
Comment on an event or entity, analogous to a post-it™ note.	**Notes or Comments**	yes	no	no	yes
Query events and entities by time, date, references, and kind of event.	**Time**	no	yes	yes	no
	Date	no	yes	yes	no
	References	no	yes	yes	no
	Type of Event	no	yes	yes	no
Place events on multiple threads.	**Multi-threaded**	no	not reported	not reported	yes
Gantt chart known problems to reverse engineer events.	**Gantt Chart**	yes	yes	no	yes
Move events around time line.	**Moveable Events**	yes	no	yes	yes
Expand/compress time line.	**Expand/Compress**	yes	yes	yes	yes
Categorize events with icons.	**Icons**	no	yes	yes	yes
Export to various formats, including power point, MS word, Visio, web, PDF.	**Power Point**	yes	no	yes	no
	MS Word	yes	no	yes	no
	Visio	not reported	no	no	no
	HTML (web)	yes	yes	yes	no
	Acrobat (pdf)	yes	no	yes	no
	Excel	no	no	no	no
Output to large plotter devices	**Plotter Capable**	yes	no	no	yes
Intuitive and user friendly interface.	**Intuitive**	yes	no	yes	yes

† Data only from Case Maps Database

Table 2 – Tool Comparison Chart – Part 2 of 2

Product Information	Name	*Analyst Notebook 6*	*Pen-Link Analyst 7*	*CaseTrak III*	*VisuaLinks*
	Company	i2	Pen-Link LTD	Badge 1022 Software	Visual Analytics
	Web Address	www.i2inc.com	www.penlink.com	members.aol.com/trakiii/	www.visualanalytics.com
	Phone Number	(703) 821-0195	(402) 421-8857	(602) 837-8427	(301) 407-2200
	Cost	$3,388 /License	shareware & commercial	DOS shareware	not reported
	Requirements Score	*8.1*	*3.8*	*3.1*	*9.2*
	Confidence Score	*10.0*	*4.6*	*9.6*	*1.5*
	Overall Score	*9.0*	*4.2*	*6.3*	*5.4*
High Level Requirements	***Defined Requirements***				
Automation of input from various sources and in various formats.	**Manual Input**	*yes*	*yes*	*yes*	*yes*
	Semi-Auto Load	*yes*	*not reported*	*no*	*yes*
	Dynamic Access	*yes*	*not reported*	*no*	*yes*
Save the customized method of data import for reoccurring formats.	**Filters**	*yes*	*not reported*	*no*	*yes*
Save bibliographical data references, kind of events, dates and times for events and entities.	**Bibliographical**	*yes*	*yes*	*yes*	*yes* [1]
	Time	*yes*	*yes*	*yes*	*yes* [1]
	Date	*yes*	*yes*	*yes*	*yes* [1]
	References	*yes*	*yes*	*yes*	*yes* [1]
Comment on an event or entity, analogous to a post-it™ note.	**Notes or Comments**	*yes*	*not reported*	*no*	*yes* [1]
Query events and entities by time, date, references, and kind of event.	**Time**	*yes*	*yes*	*yes*	*yes* [1]
	Date	*yes*	*yes*	*yes*	*yes* [1]
	References	*no*	*yes*	*no*	*yes* [1]
	Type of Event	*yes*	*no*	*no*	*yes* [1]
Place events on multiple threads.	**Multi-threaded**	*yes*	*not reported*	*not reported*	*yes* [1]
Gantt chart known problems to reverse engineer events.	**Gantt Chart**	*no*	*no*	*no*	*no* [1]
Move events around time line.	**Moveable Events**	*yes*	*not reported*	*no*	*no* [1]
Expand/compress time line.	**Expand/Compress**	*yes*	*not reported*	*no*	*yes* [1]
Categorize events with icons.	**Icons**	*yes*	*yes*	*no*	*yes* [1]
Export to various formats, including power point, MS word, Visio, web, PDF.	**Power Point**	*yes*	*not reported*	*no*	*yes* [1]
	MS Word	*yes*	*not reported*	*yes*	*yes* [1]
	Visio	*no*	*not reported*	*no*	*yes* [1]
	HTML (web)	*no*	*not reported*	*no*	*yes* [1]
	Acrobat (pdf)	*no*	*not reported*	*no*	*yes* [1]
	Excel	*yes*	*not reported*	*no*	*yes* [1]
Output to large plotter devices.	**Plotter Capable**	*yes*	*not reported*	*no*	*yes* [1]
Intuitive and user friendly interface.	**Intuitive**	*yes*	*yes*	*no*	*yes* [1]

2.3 Tools Not Investigated

- ***FileList* by Forensics, Inc**
- ***ShowFile* by Forensics, Inc**
- *TIME WIZARD* BY WIZDOM ANALYSIS TOOLS
- *FLOW WIZARD* BY WIZDOM ANALYSIS TOOLS
- *ExperienceWare*™ by PRAJA, Inc.
- *EgressPro* by SimCo Consulting
- *WinForce* by winForce Technologies
- *C-Insight* by MetaEdge Corporation
- *DB2 Intelligence Miner* by IBM Corporation

These tools were briefly reviewed because the vendor did not respond to inquiries, or the study team concluded their purpose was disparate from intelligence analysis, or both. However, the study team felt it was important for a minor sidebar discussion about these tools because they had displayed capabilities in dealing with events referenced by time and date, and the study team freely admitted their limited ability to understand the absolute needs of intelligence analysis. Therefore, these tools were included in this report to help those who may be interested in learning more about them.

2.3.1 FileList and ShowFile

FileList and ShowFile were products of Forensics, Inc. They created a time line analysis of computer file dates and times from one or more computer hard disk drives and floppy diskettes. Time lines could be created based on file access dates, file creation dates, file modification dates, and activity associated with deleting files. Identification of computer activity on weekends and outside of normal working hours could be put into a separate time line. ShowFile sorts, analyzes, and views database output created by FileList. Time line analysis of computer data would be extremely helpful in investigations and computer security reviews.

2.3.2 Flow WIZard and Time WIZard

The WIZdom Analysis Tool Suite had two useful tools called the Flow WIZard and Time WIZard tools. Flow WIZard generated process flow models for process mapping. Time WIZard was a project management tool utilizing time lines. It would be used to reverse engineer a major development project using a Gantt chart process which was one of the high-level requirements identified.

2.3.3 ExperienceWare

ExperienceWare™ was a rapidly deployable business activity monitoring solution from PRAJA, Inc[40]. Their customers included Zurich Financial Services, FOX, University of Chicago, CBS, Yahoo, General Motors, and Henry Ford Health System. The tool allowed companies to monitor business processes by plotting activity three dimensionally using location, process, and time. One could see that this could be used as a time line analysis tool, but the tool would probably be used irregularly from its design and that could become problematic.

2.3.4 EgressPro

EgressPro was a fire engineering simulator developed by SimCo Consulting, and was sold for $150 per desktop. The simulator develops time lines and movements of escape from fires based on established fire protection engineering theory. Was designed to assist architects and fire protection engineers in developing models to predict egress times for a given room, corridor or stairwell[41]. The tool runs on a Windows 95/98 or higher operating system. The tool has no direct application to intelligence analysis that the study team was aware of, but for the price it may be worthy of looking at if your analysis includes times to egress from locations that are not necessarily on fire.

[40] ExperienceWare™ Advertisement. Internet. 31 August 2002.
[41] Computer Models for Fire and Smoke. Society of Fire Protection Engineers. International Survey of Computer Models for Fire and Smoke. <http://www.firemodelsurvey.com/pdf/EgressPro_2001.pdf> 27 July 2002.

2.3.5 winForce

winForce is a commercial tool offered by winForce Technologies of Scottsdale, Arizona for $595 per desktop[42]. It was a full featured case management system designed for lawyers and prosecutors. The tool included the ability to place data entered into the system automatically onto a timeline to present information about the criminal offense, the investigation and the evidence[43]. The vendor was unresponsive to the study team's request for information. Their website is http://www.blueknighttech.com/ and includes a download section, but a trial version had to be mailed out.

2.3.6 C-Insight

C-Insight a commercial tool offered by MetaEdge Corporation of Silicon Valley is designed for customer intelligence for e-commerce business. C-Insight allows businesses to review customer traffic in a time line fashion.[44]

2.3.7 DB2 Intelligent Miner

DB2 Intelligent Miner offered by IBM includes time-sequencing functions. Although not a stand-alone tool (requires Business Intelligence Platform[45]), it could be incorporated into existing customer solutions. In a news article, a biopharmaceutical company used DB2 Intelligent Miner to determine the progressions of diseases with timelines[46].

[42] "Welcome to winForce Technologies", winForce Home Page. <http://www.blueknighttech.com/> 31 July 2002.
[43] Michael Rogers, Attorney, "WinForce Product Review", Legal Tech, November 2001, Vol. 19, No. 8, pg. 6
[44] PR Newswire, "MetaEdge's C-Insight Provides State-Of-The-Art Customer Intelligence for E-Enterprises" 12 September 2000, Financial News section.
[45] "IBM Software : Database and Data Management : Intelligent Miner Family : Overview" DB2 Intelligent Miner web page. <http://www-3.ibm.com/software/data/iminer/> 17 August 2002.
[46] PR Newswire, "AxCell Biosciences Explores Pathways to disease with IBM Database Technology" 16 August 2002, Financial News section.

III. SUMMARY

3.1 Recommendations

Based upon the given requirements, the team's research, and the information provided by the vendors, our recommendation was i2's Analyst Notebook Version 6. It was the most intuitive, was verified to have had most of the high-level requirements, and had helpful documentation. The i2 staff was also very helpful and quick to respond questions and support. Unfortunately it was not due out until the end of the 2002 calendar year.

The other tool to examine closely would be VisuaLinks by Visual Analytics.

And finally, watch for a Windows release of CaseTrak III by Badge 1022 Software. The tool remained promising, and showed well for a shareware product.

3.2 Conclusion

There were some powerful tools available for use by the IC on the commercial market, but no holy grail.[47] None of them met all the high-level requirements identified by the intelligence analysts. Of the evaluated tools, a few met most of the high-level requirements for time line analysis, and most of the tools met at least half the high-level requirements. This disparity of capabilities illustrated the time line analysis market was still maturating. There were still too few tools available. The need for better time line analysis tools still existed for increasing the MITRE Analyst Tool Shed product line and to combat the Asymmetric Order of Battle (ASOB) problem.

It is possible that the time line analysis market, and in general the automated intelligence analysis markets, will continue to evolve into a richer market of tools. Newer products could be introduced and further development of existing tools will only improve the availability and selection of time line analysis tools. Identification of analytical requirements of a customer will remain essential to determining which tool will work best for a given environment. And it may become necessary to customize existing commercial software through application program interfaces to satisfy the needs of intelligence analysts.

This market survey may serve as a baseline for future efforts at analyzing the time line analysis market. In the event that the time line analysis market does not grow, it may be practical for MITRE to develop customized API plug-ins for commercial software or to develop a tool to match the requirements of the intelligence analyst community.

3.3 Contact Information

You may direct your questions to the study team at the following phone numbers and email addresses listed in the table below:

Table 3 – Study Team Contact Information

[47] Jim Burnetti. "Timeline Analysis Tools Evaluations." E-mail to John Wigle. 31 May 2002.

Senior Advisor	Jerry Cogle	(703) 883-6277	jcogle@mitre.org
Lead Researcher	John Wigle	(703) 883-1277	jwigle@mitre.org
Researcher	Jennifer Webster	(703) 883-6039	jenw@mitre.org

IV. Glossary of Terms and Phrases

API – An acronym for Application Program Interface. An interface designed into computer programs that allow third parties to develop external software that works with the application like if it was built into the application itself. Typically, the software modules designed to work with applications through an API is called a plug-in, because it is imagined to plug into the tool. See Plug-in.

ASOB – An acronym for ASymmetric Order of Battle.

Asymmetric Order of Battle – The steps an entity goes through to ready itself for an irregular (asymmetric) offensive or defensive position. The acronym for this phrase is ASOB. Compare with Order of Battle and Signature.

DTD – An acronym for Data Table Description. A DTD is a document used to describe the data elements in a data file, so a third party will understand how the data is organized and what data is stored.

Gantt Chart – A specific type of chart used in program management that is named after an American scientist who invented it. The chart uses milestones to denote the beginning and ending of a specific task with a horizontal line drawn between them. The length of the horizontal line represents the time it takes to complete the task. The chart comprises all the tasks needed to complete a project spread out over a time line to illustrate how the long the project may take to complete. Independent parallel tasks can be shown above or below other tasks, and tasks dependent upon another task being finished first follow after the first task. The chart was designed to show the dependencies and the critical points in the project that need to be managed closely.

GIF – An acronym for Graphic Interchange Format. A photographic file format developed by CompuServer, a Internet Service Provider like American On-Line, to allow their users to exchange photos. A common graphic format used on the Internet. Compare with JPEG and SGML.

HTML – An acronym for HyperText Markup Language. HTML is an Internet standard used to exchange document information semantically, leaving the client application, called a browser, to determine the proper way to display a document.

Informix – A large-scale commercial database company, with a database application by the same name. Compare with Ingress, Microsoft Access, Microsoft SQL Server, Oracle, and Sybase.

Ingress – A medium scale commercial database application available from a company called Computer Associates. Compare with Informix, Microsoft Access, Microsoft SQL Server, Oracle, and Sybase.

Intelligence Community – The agencies and services of a government that conduct intelligence activities. In the United States the Intelligence Community is defined by membership on the National Foreign Intelligence Board. Currently there are fourteen agencies and departments having membership on this board. They are the Federal Bureau of Investigation, the Central Intelligence Agency, the Army, the Navy, the Air Force, the Marines, the U.S. Coast Guard, the Department of Treasury, the Department of Energy, the Department of State, the National Security Agency, the Defense Intelligence Agency, the National Image and Mapping Agency, and the National Reconnaissance Office.

JPEG – An acronym for Jet Propulsion Exchange Graphic. A photographic file format developed by the Jet Propulsion Labs to allow photos from space to be shared with scientists over the Internet. A very common standard used on the Internet. Compare with GIF and SGML.

Microsoft Access – A commercial software database from Microsoft Corporation that typically works only for one user or small business applications. Compare with Informix, Ingress, Microsoft SQL Server, Oracle, and Sybase.

Microsoft SQL Server – A commercial software database from Microsoft Corporation that is designed for larger scale use than Access. Compare with Informix, Ingress, Microsoft Access, Oracle, and Sybase.

ODBC – An acronym for Open DataBase Connectivity. An industry standard used to allow third party software to connect to any ODBC-compliant database. Compare with XML.

Oracle – A commercial database company, with a database application by the same name designed for large, medium and small-scale usage. Compare with Informix, Ingress, Microsoft Access, Microsoft SQL Server, and Sybase.

Order of Battle – The defined steps a country or entity goes through to ready themselves for offensive attack or defensive position. Compare with Asymmetric Order of Battle and Signature.

PDF – A file extension. Files ending with ".pdf" are written in Adobe Acrobat format. Adobe offers a free file viewer called Acrobat to allow users to read and print these files.

Plotter – A printing device used to print very large graphics, like posters, blue prints, charts, etc. D-Size plotters handle paper about three or four feet wide.

Plug-in – Software that does not work alone as an application, but plugs into a third-party software application, and provides that third-party application with enhanced capabilities it natively does not have. See API.

SGML – An acronym for Standardized Graphic Markup Language. SGML is a standard from which other mark-up languages evolved. For instance, HTML is a sub-standard of SGML. SGML is used to describe graphics in a standardize way so they can be freely shared. Compare with JPEG and GIF.

Signature – The unique characteristics that make up an intelligence event. For instance, if a person buys a ski mask, a handgun, paper, pen, and steals a car is probably preparing to rob a bank. The steps used to prepare for the robbery is called an order of battle, and the unique steps used to identify it's a bank robbery is called the signature. Compare with Order of Battle and Asymmetric Order of Battle.

Sybase – A commercial database company, with a large-scale database application by the same name. Compare with Informix, Ingress, Microsoft Access, Microsoft SQL Server, and Oracle.

Visio - A Microsoft software product name. The application is designed to draw schematics, charts and diagrams.

Wizard-like Interface – A common interface used to install applications on Microsoft Windows. The interface asks the user a series of questions. Based on the answers given, the wizard automates the process to assist the user.

XML – Acronym for eXtensible Markup Language. An Internet standard used to allow anyone understanding XML to interpret data in any source. Compare with ODBC.

Attachment 9

Significant Evaluation Issues And Ease of Use Analysis

	Issue/Tool	Analytica	Comments	Netica	Comments
1	**User/Computer Interaction**				
1a	**Icons/Push Buttons**				
	Mouse-overs	Y		Y	
	Interpretable	Y	"Show Results" difficult	Y	
	Stable	N	Node icons disappear; can bring them back with arrow icon. No warning/instructions.	Y	
	Node net-building function	Drag & drop		Point & place	
1b	**Menus**				
	Logical order (ordered File, Edit, View, etc.)	Y	File, Edit, Object, Definition, Result, Diagram, Window, Help	Y	File, Edit, Layout, Modify, Network, Relation, Style, Report, Window, Help
	Two-deep or less (no more than 3)	Y		Y	
	Other		Window menu includes "Show memory usage." Definition menu includes "Math choices."		Menus change w/open window. Relation menu includes "Decompose Equations."
1c	**Windows/Dialog Boxes**				
	Instructions/Explanations	N	Need direct support	N	Need direct support
	Internal "Help" icon	N	Can access main Help independently	Y	Dialog & relation box "?" links to main Help menu.
	Navigating between elements				
	All node boxes/views visible	N	Toggles between node map & data field views	Y	Node attribute dialog box opens probability table box.
	Tool bar	Y	Navigate using buttons.	N	No navigation through toolbar.
	Command keys/Function keys	Y	Ctrl-Tab cycles through open elements	Y	Ctrl-Tab switches between Message Window & node map; Ctrl-T opens relation table.
	Navigating within elements				
	Doubleclick on node for properties	Y		Y	

	Point & click within node map	Y	Also tab	Y	
	Tab in node properties dialog box	Y	Both point & tab	Y	
	Tab in node relation table	Y	Both point & tab	N	Point & click
1d	**Feedback**				
	Cursor changes for pointing/text	Y		Y	
	Activity processing w/completion %	?		?	
	Error/missing data warning popups	Y	Includes explanation	Y	Includes explanation
2	**Consistency/Standards**				
2a	**Windows Metaphor**	Y		Y	
	Windows key/mouse behavior				
	Shift or drag box to select multiple nodes	Y		Y	
	Esc to deselect all	N		N	
	Click in background to deselect all	Y		Y	
	Doubleclick to open node dialogs	Y		Y	
	Rightclick to open menu options	Y		N	Node attributes only
	Menus				
	Common functions where expected	Y/N	"Find" under Object Menu.	Y	
	Stable	Y		N	Enlarges when open model
	Dialog boxes				
	Title Bar & Close	Y		Y	
	OK/Cancel/Apply (in that order)	N	Cancel/OK only	Y	Location variant from standard
	Tabbed	N/A	No tabs	N	No tabs
	Tool bar				
	Icon appearance	N	Large buttons; awkward symbolism	Y	
	Icon behavior	N	Nodes drag & drop	Y	
	Functions				
	Cut/Paste (shortcut keys & menu)	Y		Y	
	Undo/Redo (shortcut keys & menu)	Y	Attributes, moving nodes & linking	Y	Building & changing network
2b	**Common Look & Feel**				
	Consistent icon/push button design scheme	Y		Y	
	Consistent dialog box design	N/A		N	Attributes dialog box style differs from probability table.
	Consistent error message design	Y		Y	

	Consistent, recognizable terminology	Y		Y	
	Consistent, recognizable color strategy	Y		Y	
3	**System Status Visibility**				
	Push buttons move when pressed	Y		Y	
	Unavailable options grayed out	Y		Y	
	Selection feedback	Y		Y	
	Processing feedback	?		?	
4	**Errors, Error Prevention & Recovery**				
4a	**Errors**				
	Error identification	Y	Warning, lexical, syntax, evaluation, system, & fatal	Y	Errors committed while using Discrete Values for Continuous values identified.
	Error explanation	Y	Each type includes explanation; let's you keep working.	Y	Missing data warnings, cyclic dependency and probability errors identified.
	Instructions for repair	N		N	
4b	**Error Prevention/Recovery**				
	System normalizes w/out notification	N	Can set to normalize	N	Normalize through Tool Bar
	System won't continue if errors are made	Y		Y	Can't close node dialog box with incorrect state information.
4c	**System Shutdown**				
	Graceful shutdown	?		N	Errors committed while using Discrete Values instead of Continuous to enter range caused program shutdown w/loss of work.
5	**Flexibility/Efficiency/Legibility**				
	Shortcut keys for frequent actions	Y		Y	
	Multiple node/link entry	Y	Copy & Paste or Duplicate	Y	Doubleclick button
	Multiple node selection	Y	Drag box or shift/click	Y	Drag box or shift/click
	Multiple node deselection	Y	Click in background	Y	Click in background
	Link reversal	N		Y	
	Wizards	N		N	
	Align function	Y	Also has equi-space option	Y	Also align through Autogrid
	Node auto-adjusts for size	Y	Command Key/Menu option	N	Control font size from menu
	Search function (finds node)	Y	Under Object menu	Y	Under Edit menu
6	**Other Functionality**				
	External OLE capability	Word, Excel		Excel	

	Regression analysis	Y		N	
	Structural learning	N		N	
7	**Visualizations**				
	Influence net	Y	Doubleclick for description	Y	Doubleclick for description
	Node relation table	Y	Data field format	Y	Dialog box
	Node property table	Y	Data field format	Y	Dialog box (doubleclick node)
	Message window	N		Y	
	Message box	Y	Popups & error messages	Y	Error messages
	Error log	N	None	Y	In Message Window
	Probability graph	Y	Labeled	Y	Labeled
8	**Print Control & Reports**				
	Page break preview	Y		Y	
	Scaling	Y	In Print function	N	
	Reports	Y	Diagrams, results, outline	Y	Nets & probability tables. Exports text files.
	Analyses	Y	Sensitivity analysis	Y	Sensitivity analysis w/report
9	**Help/Documentation**				
9a	**Type of Online Help file**	PDF	Copious documentation but critical information is scattered throughout document and tutorial. Help building net but not making it work.	WinHelp	Concise Help manual with simple explanations but not enough support for building net. Does offer references for deeper explanation.
9b	**Information Organization**				
	Table of Contents in useful order	Y	Topically arranged; bookmarked. Learn about models first, then how to create them (4th chapter).	Y	Topically arranged; learn about models first, then how to create them (2nd chapter).
	Help file searchable (key words)	Y		Y	
	Index	Y		Y	
	Glossary	Y		N	
	Information in one place	N	Need both Help & tutorial	N	Need both Help and tutorial
	Explanations complete	N		N	
9c	**Accessibility**				
	Bayesian net explanation	Y		Y	
	How to build nets	Y		Y	

	How to assign values	N		N	
	Glossary	Y		N	
9d	**Tutorial**				
	Utility	Y	Good tutorial walks user through 4 activities with explanations and rationales. User Guide instructs on more sophisticated activities.	Y	Small selection of cases listed as tutorial: tutorial is online at www.norsys.com
	Language	OK		OK	
	Scenarios for each Utility	Y	Maybe - 4 examples	N	Elementary only
	Level of complexity	OK		Some	
	Search capability (key words)	Y	PDF	Some	HTML - by chapter

Hugin	Comments	BayesiaLab	Comments	Siam	Comments
Y		Y			
Y		Y			
Y		Y			
Point & place		Point & place			
Y	File, Edit, View, Network, Options, Windows, Wizards, Help	N	Network, Database, Edit, View, Learning, Inference, Options, Help		
Y		Y			
	Network menu includes "EM Learning." File menu includes "Structural Learning."		Database, Learning, & Inference menus contain novel choices, including Target Node Characterization and Association Discovery.		
N	Need direct support	N	Need more direct support		
N	Can only get to main Help via alt-tab, if main Help was open	N	Can't even get to main Help if dialog box is open!		
Y	Node map, node relation table, & node property dialog arranged in frame.	Y	Labels, attributes & probabilities are in same box.		
Y	Navigation between Edit & Run Modes through buttons	Y	Navigate between modeling & validation modes on tool bar at bottom of window.		
N		Y	F1 for Modeling, F2 for Validation Modes.		
Y		Y			

Y		Y			
Y		Y	Both point & tab		
Y		Y	Both point & tab		
Y		Y			
?		?			
Y	Includes explanation. Only mention is in Building BNs Tutorial; compiler checks for cycle errors & probabilities that don't sum to 1. Beeps for errors.	Y	Flags formula errors. Missing data appears to be handled in database construction.		
Y					
Y		Y			
N		N			
Y		Y			
Y		Y			
Y		Y			
Y		Y			
Y		N			
Y		Y			
Y		N	Accept/Cancel		
Y		Y			
Y		Y			
Y		Y			
Y		Y			
N		Y			
Y		Y			
Y		Y			
Y		?			

Y		Y			
Y		Y			
Y		Y	Node buttons are highlighted		
Y		Y			
Y		Y			
?		?			
Y	Error message in marquee at bottom of screen.	Y	Icons on nodes w/popup		
Y	Message box notes 0 sum errors; marquee notes cyclic dependency errors, auto-normalizes probability errors		Flags formula errors.		
N		Y	Flags/prohibits cycles.		
N	Can set to beep.	N			
?		Y	Automatic function		
?		?	Probability errors are normalized		
Y		Y			
Y	Hold down shift	Y	Automatic		
Y	Drag box or shift/click	Y	Drag box or control/click		
Y	Click in background	Y	Click in background		
Y		N	Can't find in Help		
Y		Y	File importation wizards		
Y		N	Can't find in Help		
Y	Control from Properties	N	Can't find in Help		
N	Can't find in Help	Y	Under Edit menu		
N	Can't find in Help	N	Can't find in Help		

N	Can't find in Help	N	Can't find in Help		
Y	Also EM learning (batch)	Y	Other learning methods		
Y	Doubleclick for descriptions	Y	Doubleclick for descriptions		
Y	Dialog box (from icon)	Y	Dialog box (doubleclick node)		
Y	Dialog box (doubleclick node)	Y	Dialog box (doubleclick node)		
N		Y	Console		
Y	Popup warning for cycle	Y	Popups & error messages		
Y	Non-printing except network log	Y	HTML process report		
Y	Unable to display	Y	Individual node bar graphs; also temporal graphs		
N	Prints nets, nodes, probabilities	N	Prints reference marks (page number, border, vicinity)		
Y	In Print function	Y	In Print function		
Y	Nets & text as BMPs	Y	Nets and text files		
Y	Conflict analysis w/no report	Y	Target analysis w/report		
HTML	Truly terrible Help with no searchability, no index, or glossary. Explanations often in dense terminology. Limited menu with too much space devoted to trivial points.	HTML	Not as bad. TOC is arranged by topic; includes forward/backward navigation keys, and is searchable!		
N	Not arranged topically; Intro to Bayes Nets and how to create them are in HTML-based tutorials.	Y	Arranged topically		
N					
N	TOC is alphabetical				
N		N			
N	Need both Help & tutorial	Y			
N		N			
Y		N			
Y		N	Shows examples w/out steps		

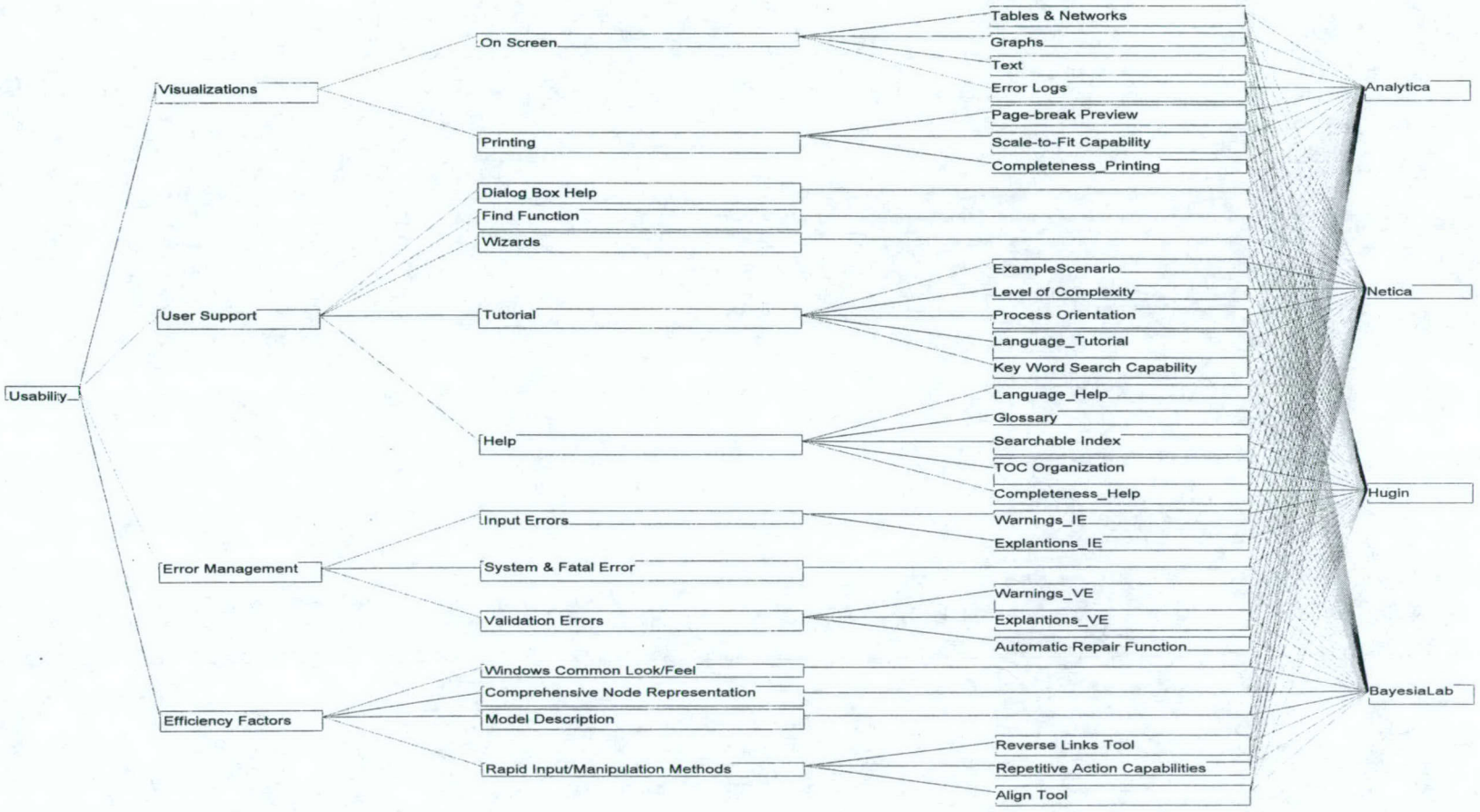
N		N	Shows examples w/out steps
N		N	
	Good online tutorial walks user through 7 activities with explanations and rationales. Language a bit dense		
Y	sometimes.	Y	PDF & HTML formats
Dense		OK	
Y	Maybe - 3 examples + cases	N	Elementary only
OK		Some	
Some	HTML - by chapter	Y	PDF & HTML formats

Issue/Tool	Analytica	Comments	Netica	Comments
User Support				
Dialog Box Help	25	None; can open Main Help	50	Links to Main Help
Find Function	100	Under Object Menu	100	Under Edit Menu
Wizards	0		0	
Tutorial				
Example Scenarios	100	Believe all are covered	50	Believe gives elementary only
Level of Complexity	100	Believe all are covered	50	Still under development
Process Orientation	100		0	Prodedural orientation
Language	100		100	
Key Word Search Capability	100	PDF-all	75	HTML-by chapter
Help				
Language	100		100	
Glossary	100		0	
Searchable Index	100		100	
TOC Organization	100		100	
Completeness	75	Had to use both Help & tutorial	50	Really needs tutorial support
Efficiency Factors				
Rapid Input/Manipulation Methods				
Repetitive Action Capabilities	100		100	
Align Tool	100		100	
Reverse Links Tool	0		100	
Windows Common Look/Feel	75	Dialog boxes & data fields	75	Dialog boxes & data fields
Comprehensive Node Representation	25	Must change screen views.	50	Nodes *or* attributes & CPT
Model Description	0		100	
Error Management				
Validation Errors				
Warnings	100	Flags *static* cyclic errors	100	Flags/prohibits cycles
Explanations	100	Probabilities & *static* cycles	100	Probabilities & cycles
Automatic Repair Function	50	Gives warning that will normaliz	100	Normalize through tool bar
Input Errors				
Warnings	100		100	

Explanations	100	Missing data, syntax, lexical	100	Discrete values for continuous; missing data
System & Fatal Errors	100	Warns to save data	0	Fatal error shut down w/out saving
Visualizations				
On Screen				
Tables & Networks	25		25	
Graphs	25		25	
Text	0	No net description capability	25	Description Window
Error Logs	0	None	25	Logged in Message Window
Printing				
Page-break Preview	100	In Window menu	100	In Layout menu
Scale-to-Fit Capability	100		0	
Completeness	100	Diagrams, objects, outlines, results (sensitivity analysis, statistics, etc.); no monitors	100	Nets, message window contents (includes CPT, sensitivity analysis)

Hugin	Comments	BayesiaLab	Comments
25	None; can alt-tab if Main Help open	0	None; can't open Main Help
0	Can't find in Menu/Tools, Help	100	Under Edit Menu
100	Structured Learning and EM (batch) Learning	100	File Importation
100	Believe all are covered	50	Believe gives elementary only
100	Believe all are covered	50	Believe gives elementary only
100		100	3rd person perspective
50	Language gets pretty dense	100	
75	HTML-by chapter	100	PDF- all; blue highlight obscures
50	Difficult to follow	0	Very bad translation
0		0	
0		50	PDF version searchable
0		0	
25	W/out tutorial one is lost	50	Really needs tutorial support
75	Must hold down shift key	100	
100		0	
100		0	
100		100	
100	Can access all from CPT	100	Can access all from CPT
0		0	
100	Flags/prohibits cycles	100	Flags/prohibits cycles
50	Cycles only; autonormalizes	50	Cycles only; autonormalizes
0	Automatically normalizes	0	Automatically normalizes
100	Only occurred for CC node	75	Inserts ! on node

50	Autofills and autonormalizes table data; explanation for Continuous Chance (CC) node	50	Hover over symbol and press W for explanation. Also processing error messages.
0		0	
25		25	
25		25	
0	None	25	Console
0	Logs errors but doesn't print	25	HTML Process Report
0		0	
100		100	
50	Nets, CPTs, monitors & junction trees. Can cut & past node, state & attributes data	100	Nets, graphs, monitors & text; target and evidence analysis reports


Usability
Visualizations
User Support
Error Management
Efficiency Factors
On Screen
Printing
Dialog Box Help
Find Function
Wizards
Tutorial
Help
Input Errors
System & Fatal Error
Validation Errors
Windows Common Look/Feel
Comprehensive Node Representation
Model Description
Rapid Input/Manipulation Methods
Tables & Networks
Graphs
Text
Error Logs
Page-break Preview
Scale-to-Fit Capability
Completeness_Printing
ExampleScenario
Level of Complexity
Process Orientation
Language_Tutorial
Key Word Search Capability
Language_Help
Glossary
Searchable Index
TOC Organization
Completeness_Help
Warnings_IE
Explantions_IE
Warnings_VE
Explantions_VE
Automatic Repair Function
Reverse Links Tool
Repetitive Action Capabilities
Align Tool
Analytica
Netica
Hugin
BayesiaLab

Attachment 10

POC List

NAME	ORGANIZATION	POSITION	PHONE	EMAIL
Greg Jannarone	NAIC/BPB	Primary Customer	937-656-1055	august.jannarone@wpafb.af.mil
Eric Braeden	NAIC/BPB	NASIC Lead	937-910-6490	Braeden@sbcglobal.net
Ken Hammerle	NAIC/BPB	NASIC Analyst	937-656-1055	kenneth.hammerle@wpafb.af.mil
Gil Kuperman	AFRL/HECA	Contract Tech Lead	937-255-3727	gilbert.kuperman@wpafb.af.mil
Capt Tim Gameros	AFRL/HECA	PSYOP Researcher	937-255-4046	timothy.gameros@wpafb.af.mil
Don Monk	AFRL/HECA	COAST (IWPC)		donald.monk@wpafb.af.mil
Dave Morton	AFRL	M&S Lead	937-255-9349	david.morton@wpafb.af.mil
Dr. Jon Pfautz	Charles River Analytics	OCCAM	617-491-3474 x541	jpfautz@cra.com
Karen Harper	Charles River Analytics	Sample, Grade	617-491-3474 x533	kharper@cra.com
Dr. Mark Sheehan	AFRL/HE	CRA SBIR PM	937-255-8806	
Bill Curtice	ASC/ENM	M&S Division Chief	937-904-4409	william.curtice@wpafb.af.mil
Joe Reiman	ASC/ENM	M&S Division	937-904-4553	
Larry Daniel	SRA	Project Manager	937-910-6433	larry_daniel@sra.com
Mike Zywien	SRA	Tech Lead	937-910-6425	michael_zywien@sra.com
Elisabeth Fitzhugh	SRA	Human Factors	937-910-411	elisabeth_fitzhugh@sra.com
Aaron Bryant	SRA	Intelligence	937-910-6426	aaron_bryant@sra.com
Ratna Bearavolu	SRA	Software	937-910-6455	ratna_bearavolu@sra.com
Rick Raftery	SRA	HUMINT	703-684-2347	rick_raftery@sra.com
Travis Lynch	JWAC	JEMNA	540-653-3757	
Phil Desmaris	JWAC	JEMNA	540-653-5757	
Bob Molepske	JWAC - Raytheon	JEMNA - Toffler	703-413-5337	
Ken Moak	AT&T	BA&PS	937-320-4571	kmoak@att.com
Lt Col Bob Rushing	JIOC	BA&PS	210-977-2484	
William Swart	JIOC			william.swart@jioc.osis.gov
Mike Millen	JIOC		210-977-2483	
Larry Willis	DARPA		(703) 696-7448	lwillis@darpa.mil
Joe Schaff	NAVAIR		(301) 904-3759	SchaffJB@navair.navy.mil
Vincente Garcia	New Mexico State Univ.			vcgarcia@psl.nmsu.edu
Ray Buettner	Naval Postgraduate School		(831) 656-3387	rrbuettn@nps.navy.mil
Dr. Julie Rosen	SAIC	SIAM	703-676-7354	julie.a.rosen@saic.com
Gary Fauss	MRC	PRFECT	505-301-2591	gary.fauss@kirtland.af.mil
Col Jack Summe				
Mrs. Graham (Sec)	USA 4th POG - Ft Bragg	Group CC	910-432-6392	
Col Alan Snyder	AIA/DO-2	AF PSYOP PMO IPT	210-977-2116	
Frank Goldstein	DO-2		210-579-3940	
Glenn Kinder	DO-2	XP Chief of PSYOP	210-977-2116	glenn.kinder@lackland.af.mil
Lt Col Doug Jaquish	ASC/RAB	Commando Solo PM	255-2211	doug.jaquish@wpafb.af.mil
Ron Swartzwelder	NSA	ASC Rep @ RA	255-4326	ronald.swartzwelder@wpafb.af.mil
Cindy Farkus	NSA		301-688-7111	
Bert Head	NSA	Dep Ops Rsrch M&S	301-688-2857	
Bill Ryder	NSA	Tech Lead Ops Rsrch M&S	301-688-4648	whryder@nsa.gov
Lt Col Francine Goode	NSA	Ops Rsrch M&S	301-688-2869	
Dr Tom Smith	NSA	DPLF Tool in OR M&S	301-688-2851	
Jeanne Jones	DIA	AFMC rep (@ NAIC)	257-3725	
Col Jeff Buckmelter	SOCOM	Mr. IW for SOCOM		
Tim Menke	SIMAF	ASC M&S	937-255-1276	
Randy Levine	SIMAF	ASC M&S	937-255-0672	
Brooke McNally	SIMAF	ASC M&S	937-255-0625	
Nicolas Rummelt	Eglin AFB, FL	Ex ASC M&S Expert	850-882-3910 x2320	

Attachment 11

Project Glossary

Project Glossary

Accessibility – Measure of whether a given target of interest can be reached (physically or by other means) to exploit a vulnerability

Analytical Hierarchy Process – A multi-criteria decision analysis technique that uses a prioritized hierarchy of criteria to aid a decision process

Alterables – Aspects of a given problem that can be manipulated, traded, or changed to help drive a solution

Bayes' Theorem – The posterior probability distribution for a given set of random variables can be calculated given an exact value for other variables

Bayesian/Belief/Causal/Probability Nets – Networks (nodes and links) used to represent dependencies between random variables; nodes (parent and child) are associated with conditional probability tables, links represent dependencies between nodes

Commercial Off-The-Shelf (COTS) – Technologies, products, and services that can be purchased directly from commercial vendors

Courses of Action (COA) – Alternative ways to approach and address a given problem

Criteria Model – A hierarchal structure with a top level goal, criteria and sub-criteria that affect the goal, and a bottom level set of alternatives; each element of the model is assigned weights, and the weights determine the influence one element of the model has on another

Data Mining - Methods and technologies associated with finding a desired piece of information in accessible data (text, video, audio, etc.) files

Decision Node Support – Support for nodes that can be used to represent the decisions and the alternatives that the user is faced with.

Decision Support System (DSS) – Computer-aided tools that emulate the reasoning process of a human expert making decisions

Decision Trees – Chronological model of a problem depicted with roots and branches; roots are decision nodes, branches represent various possibilities of the decision node (branches lead to decision nodes, chance nodes, or result nodes)

Decision/Utility Theory – A problem solving approach that strives to maximize a given utility function

Government Off-The-Shelf (GOTS) – Technologies, products, and services that can be acquired directly from other government agencies

Inference Algorithm – Algorithms that calculate the posterior probability of the variables (nodes) in the Bayesian net, given exact values of some variables

Influence Diagrams – Consists of a Bayesian Net, a Decision Node (alternative course of action), and a Value Node (value or utility of a given outcome); returns the action with the highest utility

Influence Operations – Operations focused on affecting the perceptions and behaviors of people, leaders, groups, or entire populations. The means can be physical or informational.

Mixed Graph Support – Support for both directed and undirected links in a model

Modeling – Process of representing a given problem or reality with assigned values, weights, beliefs, etc. and using inference techniques to answer queries

Psychological Effects-Based Operations (PEBO) – the deliberate use of the USAF core operational competencies and its enabling technologies as a psychological instrument.

Requirements Trace – A structured methodology to tie products, services, and technologies and components of products, services, and technologies to technical and operational requirements

Rules of Engagement (ROE) – a set of firm rules, usually framed by national policy and implemented by the Operational Commander, that govern the conduct of operations in a given theater

Social Network Analysis – Social network analysis [SNA] is the mapping and measuring of relationships and flows between people, groups, organizations, computers or other information/knowledge processing entities. The nodes in the network are the people and groups while the links show relationships or flows between the nodes. SNA provides both a visual and a mathematical analysis of human relationships. (Definition from www.orgnet.com)

Structure Learning - Technique that automatically generates a Bayesian Net, given data (in table format)

Susceptibility – A predictable path to exploit a given vulnerability

Text Mining – Methods and technologies associated with finding a desired piece of information in accessible text files

Virtual Evidence Support – Support to enter evidence into the Bayesian net which the user is uncertain about.

Vulnerability – Characteristics of a chosen target that planners and analysts can leverage and exploit

8 List of References

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